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Spread and Disappearance of the Greater Prairie-Chicken, *Tympanuchus cupido*, on the Canadian Prairies and adjacent areas

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Houston, C. Stuart. 2002. Spread and disappearance of the Greater Prairie-Chicken, *Tympanuchus cupido*, on the Canadian prairies and adjacent areas. Canadian Field-Naturalist 116(1): 1-21.

In western Canada, the Greater Prairie-Chicken (*Tympanuchus cupido*) has come and gone. Following closely on agricultural settlement, thriving on grain as an alternate food, the "Pinnated Grouse" reached Winnipeg in 1881 and Carberry, Manitoba, in 1886; Indian Head, Saskatchewan, in 1895; and Hanna, Alberta, in 1911. It spread as far northwest as Lac la Biche, Alberta. Once half the land in a given area was broken, this species diminished in numbers, retreating to local areas of thick grass around sloughs and lakes. By the late 1930s almost all were gone. Habitat factors such as fragmentation and separation of grasslands were further accentuated by cattle overgrazing, burning, and drought, and then by hybridization of surviving, isolated birds. By accessing records for the prairie provinces from nine unpublished or not-readily-available sources (unavoidably skewed by a preponderance of Saskatchewan records), I offer documentation of increases and decreases, as well as an assessment of the species' status in northeastern Montana and northwestern Ontario. I have also catalogued 131 Northern Great Plains egg sets from 36 North American oology collections. Together this material allows a more complete assessment than has been possible previously.

Key Words: Greater Prairie-Chicken, *Tympanuchus cupido*, spread, decline, extirpation, ecologic factors.

On the Canadian grasslands, the Greater Prairie-Chicken (*Tympanuchus cupido*) has come and gone. Because there is concern for many other species of grassland birds, including the Sharp-tailed Grouse (*Tympanuchus phasianellus*), and because two other species, the Sage Grouse (*Centrocercus urophasianus*) and Burrowing Owl (*Athene cunicularia*), may be facing extirpation in Saskatchewan, it seems worthwhile to summarize the spread and demise of the Greater Prairie-Chicken in western Canada and adjacent North Dakota. Are there common threads or lessons to be learned?

In this review I bring together, before it is too late, published and previously unpublished information. To provide localities and dates, and especially breeding records, I made particular use of: (a) the Andrew Graham/Thomas Hutchins combined report from Hudson Bay, 1772, (b) David Douglas' Manitoba observation of 1827; (c) responses to Mrs. Isabel Priestly's request (1943) for Saskatchewan records; (d) unpublished responses to my request for additional Saskatchewan records in 1956; (e) George J. Mitchell's 1959 *Alberta's Upland Game Bird Resource* (1959); (f) Margaret Belcher's 1961 report of museum records in Saskatchewan; (g) Dale Hjertaas' 1988 summary of Saskatchewan records since 1966; (h) Anita Steeg Kovacs' 1984 summary of newspaper accounts in southern Manitoba, 1884–1949, (i) a Montana sportsman's magazine article that adds extreme northwest Montana to their maximum range, (j) Harry Lumsden's previously unpublished reports that add northwestern Ontario to their range, and (k) oology records for the three prairie provinces and the Dakotas in major museums. This information has been brought together in one place for use by future researchers, even though most of the Saskatchewan locations have been mapped in Smith (1996). The dearth of readily available accounts largely explains the paucity of western Canadian information in Schroeder and Robb (1993).

Problem of name

The names used for prairie grouse could hardly be more confusing. Sadly, "Prairie Chicken" was, and still is, the name almost universally applied to the Sharp-tailed Grouse through western Canada. Ernest E. Thompson [Seton] in his 1890 account of the Birds of Manitoba, used "Prairie Chicken" for his account of the Sharp-tailed Grouse, and used "Prairie Hen" or Pinnated Grouse for what was then known to ornithologists south of the boundary as the Greater Prairie-Chicken. Seton's usage followed that of Macoun (1883). Macoun and Seton thus elevated the use of "Prairie Chicken" for the Sharp-tailed Grouse far beyond that of a simple and misleading folk

name and gave such use scientific standing for more than half a century. The general public and even game guardians and museum employees used "Prairie Chicken" much more often for the Sharp-tailed Grouse than for the Greater Prairie-Chicken.

For this reason, most popular accounts that refer to "prairie chickens" are suspect. In fact, nearly all of them refer to the Sharp-tailed Grouse. Johnston and Smoliak's helpful review of the Greater Prairie-Chicken in 1976 fell into this trap when they gave credence to Bulyea (1901) who unquestionably referred to Sharptails between Moosomin and Qu'Appelle, Saskatchewan; they might better have quoted Rutherford (1914), who did recognize the presence of Greater Prairie-Chicken, and, differentiated between the two species. To avoid confusion, Cooke (1885), Roberts (1936) and Johnsgard (1973) used the term "Pinnated Grouse." Although "Pinnated Grouse" referred to only one subspecies of the Greater Prairie-Chicken, and although common names are no longer assigned to subspecies, "Pinnated" is the only term that unequivocally indicates that past observers, at a given time or place, saw the Greater Prairie-Chicken.

Problem of identification

In an ideal world, one would anticipate few problems of mistaken identification between two grouse species that show such marked differences, one from the other. First, those reports that specifically mentioned the dark, rounded or squared tail, and the heavily barred underparts, offer proof of the Greater Prairie-Chicken, in sharp contradistinction to the light-coloured, elongated 'pin-tail' and finer v-shaped breast markings of the Sharp-tailed Grouse. Although the Ruffed Grouse (*Bonasa umbellus*) also has a rounded tail, its restriction to wooded areas should exclude it from consideration in most plains localities. Second, the mating rituals at the "booming grounds" of the Greater Prairie-Chicken and the "dancing grounds" of the Sharp-tailed Grouse are different. Third, as a game bird, individuals from each fall kill were available for close inspection, providing in-the-hand identification opportunities not available for many non-game species. The most credible observers are those who mentioned the two species together, for these folks clearly had an opportunity for comparison. Nevertheless, one would be naïve to expect uniform accuracy, because wishful thinking, a fertile imagination, or a faulty memory may on occasion have contributed to occasional and innocent misidentifications, particularly of sightings since 1940 — and we know not which or how many of these have been reproduced here.

Initial range

It is somewhat ironic that the Greater Prairie-Chicken was becoming extirpated in the eastern United States even as it spread west across the plains. For example, it disappeared from Tennessee in 1850, Kentucky in 1874, Arkansas in 1913, and Ohio in 1934 (Schroeder and Robb 1993), and its decline in northern Illinois began as early as 1850 (Schorger 1944). "At one time it was the leading upland game bird of the grasslands of central North America" (Robel et al. 1970). In Wisconsin in 1850, "Two sportsmen, with one dog, generally bag from fifty to eighty in a day" (Hoy 1852). "Thousands of barrels of them" were sold by market hunters (Rue and Allen 1973).

At the time of the return trip of the Lewis and Clark expedition in 1806, Greater Prairie-Chickens were present in Illinois. The sighting "highest up" the Missouri was at the James River, (now Yankton, South Dakota), on 2 September 1806 (Burroughs 1961).

T. S. Roberts (1936) stated "There were no Pinnated Grouse in Minnesota in the days of the early explorers. ... [this species] extended its range westward and northwestward just as the country was settled, keeping pace with the forefront of grainfields." Through 1850 to perhaps 1880, the range of overlap between the Pinnated Grouse and the Sharp-tailed Grouse range was very narrow, because the one species ceased where the other began (Johnsgard and Wood 1968).

The 18th-century record for Ontario

Previous accounts have overlooked Pennant's 1792 statement, "Is frequent about a hundred miles up Albany river, in Hudson's Bay." This statement is apparently derived from the Andrew Graham unpublished manuscript E.2/9, Hudson's Bay Archives, Provincial Archives of Manitoba, written probably in 1772: "Pinnated Grous [sic] is found about Henley Settlement in Hudson's Bay. Legs covered with soft brown feathers, toes naked and pectinated. The tufts which distinguish this species from all others are rooted high on the neck, not far from the hindpart of the head." (Houston et al. 2002). Henley House was situated just below the junction with the Kenogami River, about 160 km upstream from Albany on Hudson's Bay.

In 1828, the farthest north known record in Ontario of the Greater Prairie-Chicken was in Essex County, about 1000 km south of Henley House. As settlers cleared land, it spread eastward to Toronto by 1858 and north to Holland Marsh at the south end of Lake Simcoe by 1875. It then retreated, and was extirpated from the province by 1924 (Lumsden 1966). Next, the species spread north in Michigan to Sault-Ste. Marie, then gradually colonized Manitoulin Island, from west to east, between 1941 and 1962, before being swamped through hybridization with the Sharp-tailed Grouse, newly arrived from the north (Peck and James 1983).

Overlooked record near present Winnipeg

All previous accounts, save that of Roberts (1936), have overlooked an important record. In the first six days of August 1827, David Douglas, under the heading *Tetrao cupido*, "killed several birds of this species between Red River and Pembina in 49° north latitude. This may, perhaps, be found to be its most northern range" (Douglas 1829). Douglas arrived at Fort Garry, within present Winnipeg, on 12 July 1827 and stayed until 10 August. He made a number of one-day botanizing trips and one two-day trip on 23–24 July from Fort Garry to Whitehorse Plain, 29 km west up the Assiniboine River. On 1 August he went on horseback to a low hill about 27 km east of Fort Garry (Douglas 1914). His Greater Prairie-Chickens must have been collected much closer to Fort Garry than to Pembina. In view of Douglas' single record of this species within Manitoba in 1827, Roberts' claim that there were none in Minnesota through 1850 is probably an error.

Spread into Northwestern Ontario (Figure 1)

The only published observation in northwestern Ontario, of "occurrence" with "no indication of breeding," is in an eight-page mimeographed list, *Birds of the Canadian lakehead area*, by K. Denis (1940, cited by Peck and James 1983: 137). Nevertheless, Greater Prairie-Chickens were present between 1920 and 1940 near Warroad, Minnesota, at the southwestern corner of Lake of the Woods, and east along the Rainy River, the United States–Canada boundary, to Fort Frances (The last booming was heard 5 km southeast of Warroad in 1963; J. L. Ruos, Leader, Grouse Research Project, Minnesota Game and Fish, letter to Harry G. Lumsden, 16 December 1963). It also occurred within northern Minnesota as far east as Duluth until 1952 (Green and Janssen 1975). Slightly farther north, near Dryden, Ontario, Chief Ranger John Anderson in 1944 reported to Lumsden that he saw 10 to 15 grouse with yellow-orange neck patches displaying near the four-mile corner of the Rice Lake loop road, east of Quibell. Ontario Conservation Officer A. R. Olsen (six-page report to Lumsden, 1959) interviewed long-time farmers west of Dryden and determined that, after they cleared the bush for farming, Sharp-tailed Grouse moved in and increased until the 1920s, accompanied by a few Greater Prairie-Chicken, which were preferred for food because of their larger size. On 8 April 1959, 5 km north and 1 km east of Minnitaki post office west of Dryden, Olsen observed a dancing ground of 2 hectares on a stubble field with six birds. When flushed, two were positively identified as Pinnated Grouse and the other four as Sharptails. The above observations appear to add a new species to at least the hypothetical bird list for Northwestern Ontario.

Spread into Manitoba (Figure 1)

The spread of the Greater Prairie-Chicken into, and across, Minnesota, beginning about 1850, has been well documented by Roberts (1936). Cooke (1885) reported from Moorhead, Minnesota, its invasion of the Red River valley of Manitoba: "Its northern range has always fallen short of our northern boundary until last summer, when they invaded Manitoba. Mr. C. W. Nash of Portage la Prairie, says: 'This autumn we had a curious influx of the Pinnated Grouse. I imagine that they, like some other birds, are following up civilization, for until last year (1884) none were seen by the Indians and half-breed hunters.'"

The Greater Prairie-Chicken then spread west roughly in concert with white settlement. In Manitoba it reached Winnipeg in 1881, Portage la Prairie in 1882 (Nash *in* Cooke 1888), Carberry in 1886 (Thompson 1890), and Aweme/Treesbank in 1888 (Criddle 1929). Alex McArthur gave a talk on winter birds in January 1887 and reported that the previously absent Pinnated Grouse was "now quite common ... The reason for its rather sudden appearance and rapid increase seems to be that it has followed the wheat fields." C. P. Forge collected at least 17 Greater Prairie-Chicken egg sets near Carman, Manitoba, 1900–1904 (Table 1, Houston and Bechard 1987b).

Four decades after their arrival in Manitoba, they were still at a booming ground near Carberry (Symons 1967). They spread north as far as Swan River (specimen in 1938; Minish 1987a), Peonan Point (specimen) and Grand Rapids (sight record) (Godfrey 1966). According to T. Schindler, they reached their highest numbers at Oak Hammock Marsh in the 1920s (Gardner 1981).

Spread into Saskatchewan (Figure 2)

In Saskatchewan, Greater Prairie-Chickens spread and multiplied rapidly. One was killed at Indian Head late in 1895 (Macoun 1900). The first Saskatchewan nest was found at Crescent Lake, near Saltcoats, in 1897 (Table 1), where from 1910 to 1920 they were as common as the Sharp-tailed Grouse (Baines 1956), a claim made also by Ferry (1910) at the Quill Lakes in 1909. Greater Prairie-Chickens reached Tullis after 1906 (Roy 1996). Their presence on intensively farmed land near Regina was short-lived, but they were numerous 5 km west of that city on 30 September 1913 (H. H. Mitchell, *in* Belcher 1961), and were also seen 8 km south of that city on 27 April 1913 (Buchanan 1914). They reached the Battleford district in 1913, and there were "large flocks" at Lloydminster in 1914 (Bradshaw 1915). In 1914, J. D. Soper (1970) found "a few" at a ranch 10 km south of Broadview, but when he returned from late April to early June 1921, he saw none, though residents reported a few still

FIGURE 1. Localities mentioned in Manitoba.

present. In 1915 George Lang reported large flocks of prairie grouse at Indian Head, approximately one-half being Greater Prairie-Chicken or hybrids (the only mention of hybridization located in the Saskatchewan game reports). At Indian Head in the winter of 1916–1917 they were sufficiently common that George Lang, voluntary game guardian, observed seven dead birds within one mile; they had been killed by flying into telephone wires (Bradshaw 1917). They appeared at grain baits at Raymore in the winter of 1916–17 with flocks of Sharp-tailed Grouse (Charles Harris *in* Wayne C. Harris, unpub-

FIGURE 2. Localities mentioned in Saskatchewan.

lished manuscripts). In 1918, H. F. Ward at Pennock near Saltcoats reported a "surprising number" of Pinnated Grouse, including one covey of eleven, up to six or seven in other flocks, and several singles (Bradshaw 1919).

At Ituna they were first seen about 1910, five or six years after initial settlement, when little land was yet broken; H. M. Rayner saw an occasional covey until the fall of 1943 when he flushed eight birds 3 km NNE of Ituna (letter, 4 March 1956). Fred G.

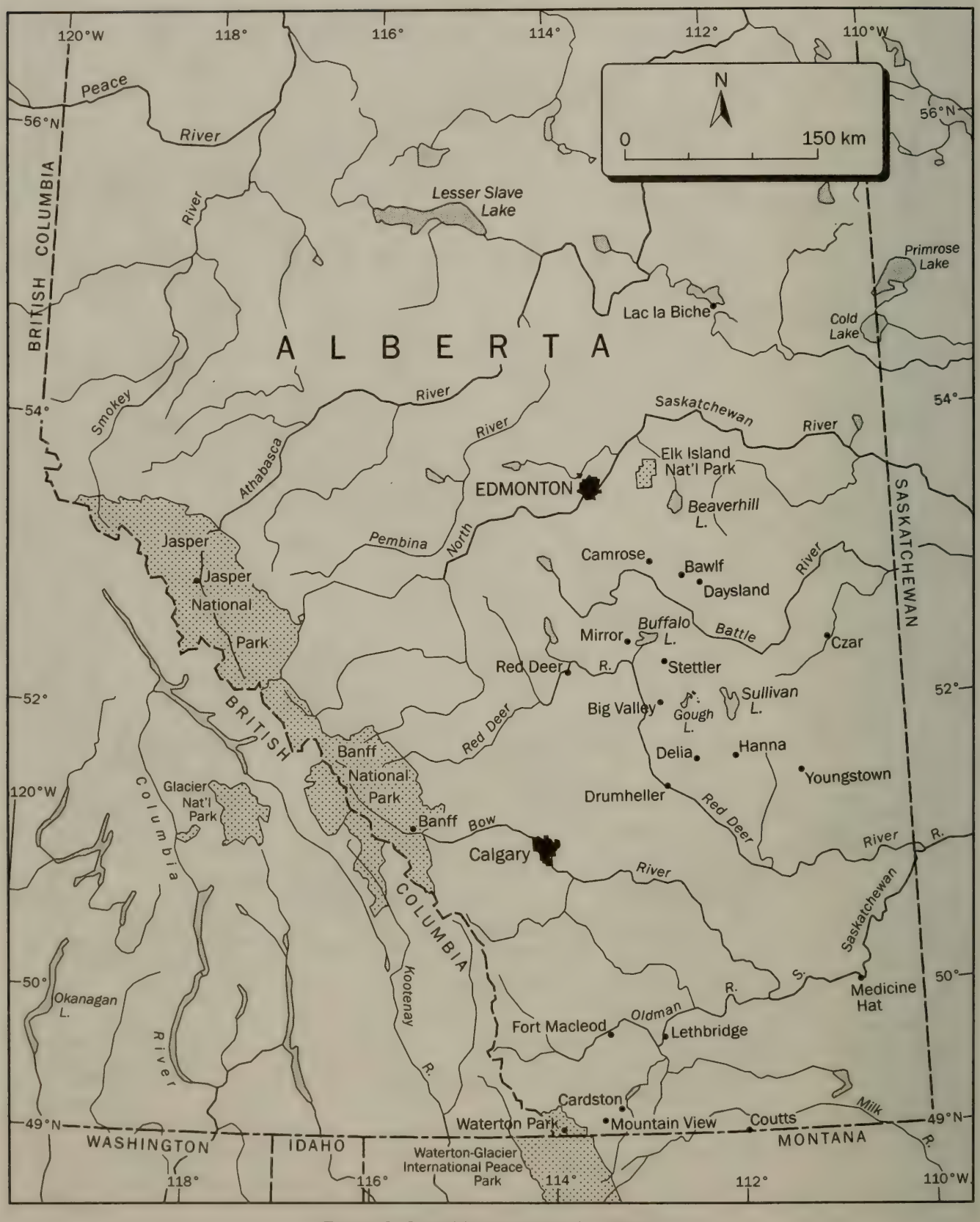

FIGURE 3. Localities mentioned in Alberta.

Bard found them still common, evidently breeding, at Dafoe in both 1928 and 1929, and collected an adult specimen on 25 April in the latter year (Belcher 1961).

The Greater Prairie-Chicken reached the northern limit of its range in longitude 102° at Kamsack in 1907 (Fraser 1961). Farther west it reached Edam in 1913 where W. E. Lake collected one on 13 September (Belcher 1961). By 1914 it had reached the Onion Lake Indian Reserve, near the Alberta boundary north of Lloydminster (Bradshaw 1915). The species was already present at Somme when Wallace Black homesteaded in 1920, and it reached Tisdale in 1923 (Houston and Street 1959). By 1924

TABLE 1. Greater Prairie-Chicken egg sets, Northern Great Plains (see acknowledgments for institute initials)

Locality	# sets	sets c eggs	eggs/set	Day/Mo	Year	# eggs	Collector	Institution
Unknown	**4**	**3**	**10.67**			**32**		
unknown	—			—	1905	7	J Kowal	PMA
unknown	—			—	—	12	J Kowal	PMA
unknown	—			—	—	(1)	J Kowal	PMA
unknown	—			20 May	1930	13	—	ASC
Alberta (AB)	**2**	**2**	**11.50**			**23**		
Stony Plain				—	1901	14	SSS Stansell?	PMA
Heatherdown				—	—	9	M Pollack/Wilby	PMA
Saskatchewan (SK)	**13**	**8**	**10.88**			**87**		
Crescent L				24 May	1897	11	F Baines	WFVZ
Saltcoats				—	1915	—	N Jowsey	PMA
Saltcoats				—	1915	(2)	N Jowsey	PMA
Melville				30 May	1920	10	HC Grose	SMNH
Wauchope				20 May	1923	(4)	HH Pittman	USask
Wauchope				10 May	1924	(1)	HH Pittman	SMNH
North Portal				3 May	1925	12	GF Abbey	PMYU
S of Gainsborough				12 May	1925	14	GF Abbey	RBWWF
Wauchope				25 May	1925	(1)	HH Pittman	USask
5 mi nw Antler ND*				6 June	1925	11	GL Davy	WFVZ
5 mi nw Antler ND*				29 May	1927	9	GA Withey	WFVZ
4 mi nw Antler ND*				8 June	1927	10	GL Davy	WFVZ
5 mi nw Antler ND*				14 June	1927	10	GA Withey	SBCM
Note: those four with ND* probably were in Saskatchewan								
Manitoba (MB)	**32**	**30**	**10.03**		**301**			
Shoal Lake				8 June	1894	6 ne	E Arnold	WFVZ
nr Reaburn				9 June	1894	12	W Raine	NMC
Morris				17 May	1896	?	PB Peabody	MPM
Beulah				29 Apr	1899	2 ne	AJ Dennis	DMW
Long L nr Reaburn				10 June	1899	8	W Raine	WFVZ
Carman				30 May	1899	13	JW Preston	ROM
Carman				—	—	8	JW Preston	OSUM
nr Roland				25 May	1900	8	CP Forge	WFVZ
Carman				28 May	1901	9	CP Forge	OSUM
Barnsley				29 May	1901	13	WC Bradbury	DM
Salterville				30 May	1901	8	CP Forge	NYSM
Salterville				10 June	1901	11	CP Forge	WFVZ
Myrtle				15 May	1902	9 ne	CP Forge	WFVZ
Salterville				17 May	1902	8	CP Forge	WFVZ
Salterville				17 May	1902	11	CP Forge	WFVZ
Myrtle				19 May	1902	8	CP Forge	MVZ
nr Roland				31 May	1902	10	CP Forge	WFVZ
Myrtle				31 May	1902	17	CP Forge	FMG
Myrtle				21 June	1902	10	CP Forge	WFVZ
Myrtle				21 June	1902	15	CP Forge	WFVZ
Madford/Wadhope?				2 July	1902	13	J Labarthe	UNR
Myrtle				5 June	1903	10 ne	GE Congdon	WFVZ
Elm Point				20 June	1903	10	CP Forge	WFVZ
e of Carman				24 May	1904	14	CP Forge	AMNH
Salterville				24 May	1904	9	CP Forge	USNM
MacDonald				22 June	1905	6	CP Forge?/Wilby	PMA
Lake Winnipeg				2 June	1905	10	DWilby	NMC
Douglas				1 June	1916	**	CH Young	NMC
Kalevala				28 May	1921	12	ES Norman	SBCM
Kalevala				30 May	1921	13	ES Norman	UMMZ
Oaklands				11 June	1927	6	AG Lawrence	NMC
St. Francis Xavier				4 June	1928	12	AG Lawrence	NMC

Continued

TABLE 1. *Continued*

Locality	# sets	sets c eggs	eggs/set	Day/Mo	Year	# eggs	Collector	Institution
North Dakota (ND)	**52**	**50**	**11.86**			**593**		
Wahpeton				—	—	11	JK Jensen	SBCM
Church's Ferry				14 June	1892	6	ES Bryant	WFVZ*
Devils Lake				21 May	1895	9	WF Hill	FMNH
Rock Lake, Towner Co.				12 June	1895	12	RS Judd	PMYU
Pembina				23 May	1898	15	PB Peabody	WFVZ
Pierce Co. [Buffalo Lake]				21 May	1900	13	F Maltby	NYSM
Stump Lake				31 May	1901	13	HK Job	USNM
Eddy Co.				15 May	1902	—	DR Ducks	UMMZ
Eddy Co.				20–23 May	1902	—	DR Ducks	UMMZ
Duck Lake				18 May	1902	16	NA Francis	MCZ
Lakota				23 May	1902	13	NA Francis	MCZ
Arthur, Cass Co.				29 May	1904	9	AD Doerge	SDNHM
Rock Lake				26 May	1909	14	RS Judd	PMYU
Ward Co.				15 May	1916	15	EJ Booth	MVZ
8 mi W Deering				18 May	1917	16	GC Withey	WFVZ
2 mi NW Antler				18 June	1917	13	GA Withey	DMW
4 mi W Deering				22 May	1923	14	GC Withey	UWGB
nr Deering				24 May	1923	12	GC Withey	WFVZ
12 mi W Antler				3 June	1923	10	D Ogg	CM
6 mi S Flaxton				26 May	1924	13	GF Abbey	WFVZ
10 mi E Deering				28 May	1924	9	GC Withey	WFVZ
4 mi N Denbigh				28 May	1924	7	GC Withey	SBCM
5 mi E Deering				28 May	1924	16	GC Withey	WFVZ
4 mi E Deering				31 May	1924	10	GC Withey	UWGB
5 mi E Deering				31 May	1924	12	GC Withey	UWGB
7 mi NE Flaxton				5 June	1924	12	GF Abbey	SBCM
2 mi E Antler				27 May	1925	9	GL Davy	PMYU
3 mi NE Deering				31 May	1925	14	GA Withey	MVZ
6 mi SW Antler				19 May	1926	14	GL Davy	WFVZ
N of Antler				21 May	1926	10	GA Withey	WFVZ
6 mi E Deering				11 May	1927	13	GA Withey	DMW
2 mi SW Antler				12 June	1927	11	GL Davy	WFVZ
5 mi SE Antler				12 May	1928	9	GA Withey	WFVZ
4 mi SE Antler				18 May	1928	15	GA Withey	WFVZ
Antler				1 June	1929	12	GA Withey	SBMNH
NE Deering				19 May	1930	14	GC Withey	WFVZ
NE Deering				25 May	1930	14	GC Withey	PMYU
NE Deering				6 June	1930	11	GC Withey	PMYU
NE Deering				6 June	1930	11	GC Withey	PMYU
McHenry Co.				20 May	1931	10	GC Withey	USNM
McHenry Co.				24 May	1931	12	GC Withey	WFVZ
McHenry Co.				24 May	1931	13	GC Withey	NYSM
3 mi SE Antler				31 May	1931	12	GL Davy	WFVZ
McHenry Co.				5 June	1931	8	GC Withey	WFVZ
McHenry Co.				14 May	1932	13	GC Withey	WFVZ
McHenry Co.				20 May	1932	12	GC Withey	WFVZ
McHenry Co.				12 June	1932	13	GC Withey	SBMNH
McHenry Co.				18 May	1933	9	GC Withey	CU
McHenry Co.				26 May	1933	11	GC Withey	CMNH
McHenry Co.				13 May	1934	12	GC Withey	WFVZ
McHenry Co.				8 June	1934	10	GC Withey	WFVZ
2 mi E Loraine				???	1934	11	GC Withey	Minot
South Dakota (SD)	**28**	**26**	**10.96**			**285**		
Yellowstone R.				???	1871	8	FV Hayden	USNM
Vermilion				17 May	1879	9	GS Agersborg	MCZ
Vermillion				26 May	1882	8	HB Bailey	AMNH
Vermillion				27 May	1882	8 ne	HB Bailey	AMNH

Continued

TABLE 1. *Continued*

Locality	# sets	sets c eggs	eggs/set	Day/Mo	Year	# eggs	Collector	Institution
Vermillion				30 May	1882	8	HB Bailey	AMNH
Vermillion				30 May	1882	7	HB Bailey	AMNH
Flandreau, Moody Co.				2 June	1882	11	HB Bailey	WFVZ
Egan, Moody Co.				16 June	1882	?	(via BF Goss)	MPM
Vermillion				16 June	1882	8	HB Bailey	AMNH
Vermillion				23 June	1884	10	GS Agersborg	CAS
Roswell, Miner Co.				May	1888	12	FA Patton	UMA
Sanborn Co.				7 May	1889	10	FA Patton	WFVZ
Miner Co.				May	1889	11	FA Patton	AMNH
Roswell, Miner Co.				14 May	1889	12	FA Patton	HSU
Miner Co				17 May	1890	12	A Hewitt	WFVZ
Harrison				18 May	1890	10	WC Colt	MVZ
Miner Co.				10 May	1891	14	FA Patton	USNM
Harrison				25 May	1891	12	WC Colt	MVZ
Roswell				2 June	1891	11	BV Jones	BMNH
Bryant				20 May	1895	15	HE Lee	USNM
Watertown				25 May	1895	10	GW Dixon	WFVZ
Sanborn Co.				14 May	1898	15	FA Patton	WFVZ
Hamlin Co.				13 May	1903	15	HE Lee	OMNH
Hamlin Co.				16 May	1903	14	HE Lee	MVZ
Rondell, Brown Co.				18 May	1905	10	J Collins	WFVZ
Armour, Douglas Co.				6 May	1911	10	A Walker	WFVZ
Sanborn Co.				20 May	1914	—	FA Patton	Earlham
Sanborn Co.				1 June	1922	15	FA Patton	UAM
Grand Total	**131**	**119**	**11.10**			**1321**		

Notes: In 7th vertical column, ** indicates that a single egg was obtained from an oviduct. Egg numbers in parentheses, from incomplete sets, are not counted in totals. In 8th vertical column, ne = eggs no longer extant; otherwise, ne means northeast. In 10th vertical column, WFVZ* indicates set came from Cumberland Science Museum, Nashville Tennessee.In some clutches in some collections, some of original eggs are no longer extant, but are still counted: e.g., Stony Plain, Alberta, there are now only 11 eggs remaining from original set of 14. Institution abbreviations in 8th vertical column can be found alphabetically in Acknowledgements.

H. H. Mitchell reported it as "fairly common resident in transition zone, apparently extending its range northwestward," and Bradshaw's annual report of the game commissioner said it was now "reported from almost all points where the [Sharptail] occurs." Andrew Holmes reported "several fairly large coveys" at Davis and Henribourg, south of Prince Albert, in the fall of 1924 (Bradshaw 1925).

Spread into Alberta (Figure 3)

No reliable dates exist for the arrival of the Greater Prairie-Chicken in Alberta; it was never common there. Whether the "old-timers" correctly remembered it in the late 1890s, as told to Rowan, seems highly doubtful (Mitchell 1959). However, by 1911 and 1912 it was "common" in the Hanna district (Mitchell 1959), and several were shot in eastern Alberta in the fall of 1913 (Lawton 1913). Thus in 30 years it had spread west 1000 km from Winnipeg, at an average rate of about 33 km per year, doubling the speed of its Minnesota - North Dakota spread. The first specimen from the Red Deer area was shot near Buffalo Lake, east of Mirror, by George Cook on 26 December 1914 (Horsbrugh 1918). Single individuals were shot near Bawlf in 1916 (Farley 1932), in the Delia area northeast of Drumheller in 1918 (Mitchell 1959), and south and east of Camrose in October 1926 (Farley 1932). It was hunted near Calgary and Edmonton, and seen north to Lac la Biche (Rowan 1926; Salt and Salt 1976). It nested near Buffalo Lake. Three nests were found at the south end of Beaverhill Lake, 17–18 May 1924 (Salt and Wilk 1958; Farley 1932; Mitchell 1959; Lister 1979). Three or perhaps four booming grounds near Beaverhill Lake were in use in 1925. William Rowan's field notes show it was also common at Gough Lake and east of Big Valley, 1920–1925. In a letter to George J. Mitchell dated 15 April 1957, Rowan told of "breeding populations"at Sullivan Lake in 1924, and also at Wavy Lake east of Daysland. Salt and Wilk (1958) mapped only nine known localities of occurrence in Alberta.

Stable period in Saskatchewan, 1910–1920s

The open, fertile plains, quickly broken and planted to wheat and other grains, interspersed with sum-

TABLE 2. Main Collectors of Greater Prairie-Chicken egg sets Northern Great Plains

Collector	# sets	State, Prov	Years	
G. C. Withey	24	ND	1917	1934
C. P. Forge	16	MB	1900	1905
G. A. Withey	7	ND, SK	1927	1929
G. L. Davy	6	ND, SK	1925	1927
F. A. Patton	7	SD	1888	1922
H. B. Bailey	6	SD	1882	
G. F. Abbey	4	ND, SK	1924	1925
H. H. Pittman	3	SK	1923	1925

First egg set, 1879, Vermilion, South Dakota, G. S. Agersborg. Last set, 1934, McHenry Co., South Dakota, G. C. Withey, 43 sets in Western Foundation of Vertebrate Zoology. 50 museums and university collections contacted. 36 had Northern Great Plains egg sets.

merfallow every second or third year, soon offered insufficient cover for Greater Prairie-Chicken in the flattest and most intensively farmed areas.

Regions that remained attractive were grassy, low-lying, somewhat moist areas such as those around Old Wives Lake, the north end of Last Mountain Lake, and the Quill Lakes, together with areas in the Qu'Appelle Valley. H. H. Mitchell sighted them at Craven on 15 February 1916 and at Imperial Beach on 24 October 1922 and collected specimens at Imperial Beach on 27 October 1922 (two), and 21 October 1924. H. Eutenner (Euteneir?) shot one at Holdfast in 1920 and presented it to Mitchell at the museum; a specimen from R. A. McEwen at Nokomis had no date. (Belcher 1961). They were still present southwest of Snipe Lake until 1926, when Elizabeth [Hubbard's] family moved to Grenfell (Hubbard 1976). Several birds were seen near Big Quill Lake at Dafoe on 10 and 11 October 1930 by Bradshaw and Bard (Belcher 1961). Four were seen at the north end of Last Mountain lake by F. G. Bard on 5 June 1936 and J. D. Soper saw a single bird at Watrous on 5 July 1936 (Soper 1970).

In the Weyburn and Virden map sheet areas in southeastern Saskatchewan, they were "common and widespread" from 1910 to at least 1920. At Percival, John Nelson's oldest brother shot one about 1928. Ralph Stueck at Abernethy and Ken Skinner at Katepwa Lake saw them regularly in the 1920s but they disappeared in the late 1930s (Callin 1980). R. D. Symons (1967) observed a booming ground near Moosomin, presumably in the 1920s.

In the Moose Jaw area, sportsmen found them common through at least the early 1930s. Hugh McCrea had sightings at Old Wives Lake in the early 1930s and Tom Beveridge had them at Mortlach in 1934, where they persisted until at least early 1942 (Knight 1967). In the Allan Hills, where he farmed in the upper Arm River valley northeast of Davidson, 1920–1925, R .D. Symons heard the "booming, hollow note ... in those crocus-sweet spring mornings ... awakened ... from sleep at daybreak" (Symons 1967).

Along the United States boundary a few were still present in 1927: one near Altawan, 8 August, several at Lonesome Butte, south of Lafleche, 9–17 September, and two at Buffalo Gap south of Willowbunch on 10 September (Soper 1970).

Montana

If this species indeed migrated south (or southeast?) in winter and if the 1965 and 1972 sightings in extreme southern Alberta originated from Montana, one would expect records across northern Montana, south of Alberta and western Saskatchewan. Such records do not exist. Saunders' state list in 1921 recorded only a single specimen from a most unexpected location, deep within the state and not even in good prairie chicken habitat (Bob Eng, personal communication), shot by John R. Bane near Huntley, northeast of Billings, in the fall of 1917 (Saunders 1921). P. D. Skaar (1987) doubted the validity of this record, believing that Saunders had not seen the specimen. If valid, might it have reached Huntley on a railroad flat car?

Only in the extreme northeast corner of Montana (Sheridan County) have there been credible records at any time. The first record is for the sandhills 40 km north of Culbertson, west of the present hamlet of Medicine Lake, in 1904, when J. B. Lyons shot over 200 'squaretails' in four days. A hunter shot two south of the hamlet of Homestead, 10 km farther south, about 1919. Joseph A. Morin saw them in the Wolf Creek area southwest of Plentywood in the fall of 1936. That year, William T. Krummes, assistant manager of the Medicine Lake National Wildlife Refuge (NWR), listed them as rare, but included a photo of a booming male just north of Medicine Lake. Frank Reuter, a rancher near Medicine Lake, had a large booming ground in a hay meadow until about 1940–41. Farther south, in the Yellowstone valley near the hamlet of Intake between Glendive and Savage, Art Suckow gave a description of seven or eight seen in early June 1944, the last credible record in Montana (Walcheck 1980). A careful survey of Sheridan County by Bob Eng (personal communication) in 1952 revealed no sight or sound of Greater Prairie-Chickens, but after a hiatus of 23 years there was a single unconfirmed report in 1961–62.

North Dakota

In North Dakota, the arrival and distribution are well documented, after it had "followed the plow ... five hundred miles ... in fifty years ... an average of

ten miles a year" (Partch 1973). The Greater Prairie-Chicken was first reported at Grand Forks in 1880, and had a "booming ground" in the most northeasterly county, Pembina, by 1882. By 1884, it was common at Fargo and had moved 100 km west of there, a spread of 500 miles (800 km) in 50 years. By 1900, this species had spread westward almost exactly to the Montana boundary; it was 40 km short of the Montana boundary at Medora; 27 km from it at Williston; 8 km from it at Marmarth and 3 km from the boundary at Beach (Walcheck 1980); at that time it occupied all but the extreme southwestern corner of North Dakota.

Between 1917 and 1934, enthusiastic oologists, David Ogg, his son-in-law, George L. Davy, and his friend George A. Withey, collected 37 clutches in McHenry and Bottineau counties, especially near Antler, North Dakota, which is just a few km south of the junction of Manitoba and Saskatchewan with the 49th parallel (Table 1, Bechard and Houston 1984). As late as 1940, roadside counts gave an estimated North Dakota state population of 430 000 individuals, falling to 4,000 to 5,000 by 1964 and fewer than 400 by 1972 (Stewart 1975). On the Arrowwood NWR, 360 Greater Prairie-Chickens and 2100 Sharp-tailed Grouse were counted in 1941, dropping to zero prairie chickens and 250 Sharp-tailed Grouse by 1966 (Kirsch et al. 1973). "When the proportion of grain to grassland was about 20 to 80, the Pinnated moved in and began to increase ... As the proportion moved up to 50:50, the population ... increased to tremendous figures ... But then the ratio tipped over the other way, and there was more land in crop than in native grassland. Then the pinnate could find plenty of food but no nesting cover ... or escape cover. He was literally plowed out of house and home" (Anonymous 1953). By 1997, the spring breeding population in North Dakota was "about 300 with most living on or near the Sheyenne National Grassland" (Kobriger 1999).

Saskatchewan breeding records (including flightless young)

The first Saskatchewan nest in 1897 has been mentioned above. H. C. Grose collected a set of 10 eggs near Melville on 10 June 1918 (Houston 1993). Pittman at Wauchope found nests with eggs in three successive years, 1923, 1924 and 1925 (Nero and Lein 1971). The enthusiastic oologist group residing in Antler, North Dakota, within 3 km of the Canadian boundary, collected at least two sets within Saskatchewan, and four other sets that were either within Saskatchewan or within one mile of it: 11 eggs on 6 June 1925, 9 eggs on 29 May 1927, 10 eggs on 8 June 1927, and 10 eggs on 14 June 1927 (Table 1). The sets definitively named as from within Saskatchewan, 12 eggs from North Portal on 3 May 1925, and 14 eggs south of Gainsborough on 12 May 1925, were both collected by George Abbey (see Table 1 and also Bechard and Houston 1984). At Quill Lake, five chicks were seen 18 June 1929 by Fred Bradshaw, and a female with a brood was seen there by Todd (1947), 20 June 1932. J. P. Maywood found a nest with 14 eggs, 6 km southwest of Nipawin, 22 June 1947. M. G. Street flushed a female with seven young near Nipawin on 28 July 1947 (Houston and Street 1959). Wallace Black had several nest records at Somme, 1920–1942 (Hooper 1992). Peter McLellan found a hen with three young in deep grass 3 km east of Arcola on 13 September 1955 (letter, 13 September 1955). The latest report was an adult with eight half-grown young in a long grass meadow in Cypress Hills Provincial Park, 14 July 1966 (Pegg 1967).

Migration?

Did some Greater Prairie-Chickens migrate? Salt and Wilk (1958) explained the absence of winter sightings in Alberta (but note the 26 December 1914 specimen above) with the remarkable but unsubstantiated claim that Greater Prairie-Chickens "left the province during the winter." There is reasonable evidence (Cooke 1885) that females, especially, migrated from southern Minnesota and northern Iowa to southern Iowa and northern Missouri. However, Hamerstrom and Hamerstrom (1973) found no evidence of migration in their local Wisconsin population.

Museum egg data sets

Because of the paucity of other breeding records in the five jurisdictions, my wife Mary joined me for a week in the Western Foundation of Vertebrate Zoology, transcribing 3660 egg data sets for all Northern Great Plains species, including 34 Greater Prairie-Chicken sets. We also transcribed data in the Saskatchewan Museum of Natural History (SMNH) and the University of Saskatchewan Biology Museum (USask). Next, I wrote to all museums reported by Kiff and Hough (1985) to hold egg sets, and collated their data (Table 1).

Museum egg data are the best breeding evidence extant for many localities in many years. They also provide average numbers of eggs per set: 11.5 in Alberta (n = 2); 10.9 in Saskatchewan (n = 8); 10.0 in Manitoba (n = 30); 11.9 in North Dakota (n = 50); and 11.0 in South Dakota (n = 26) (Table 1).

Relative numbers

Relative abundance has several times been stated in terms of the numbers of their nearest related species. In 1886, near Winnipeg, Greater Prairie-Chickens were about half as common as the Sharp-tailed Grouse (Nash, *in* Thompson 1890). Near Saltcoats from 1910 to 1920 they were as common as the Sharp-tailed Grouse (Baines 1956), a claim

made also by Ferry (1910) at the Quill Lakes in 1909. In southern Saskatchewan, they were the "commonest upland game bird ... the real open prairie dwellers" at some unspecified time after 1905 (Taylor 1955). Rutherford (1914) claimed that "grouse, pinnated, ruffed and sharptail, are to be had in immense numbers." In adjacent North Dakota, E. T. Judd (1927) found that the Greater Prairie-Chicken was "practically unknown" in the early 1890s, but increased after 1910 to become common by 1915: "if it continues to increase as it has in the past five years it can soon be classed as an abundant bird," to a large extent replacing the Sharp-tailed Grouse. Near Raymore, Saskatchewan, it increased rapidly in three years to become equivalent in numbers to the Sharp-tailed Grouse about 1920 (Charles Harris *in* W. C. Harris, unpublished manuscript).

Ten-year population cycle

Greater Prairie-Chicken did not persist long enough on the Canadian prairies for a population cycle to become evident. Elsewhere, Minnesota populations peaked in 1863, 1871, 1880–81, and 1894–95, and a century later in 1982 and 1992; in Wisconsin they peaked in 1940, 1950, and 1970–71 (Svedarsky et al. 1997). This approximate ten-year cycle is similar to that of the Great Horned Owl, Snowshoe Hare, Lynx, and to that of other upland game birds, the Ruffed Grouse, Sharp-tailed Grouse and Spruce Grouse elsewhere in North America (Houston et al. 2002, in press).

Habitat requirements

"...wildlife abundance or scarcity is fundamentally a function of habitat suitability. ... nest-brood cover [is] the weak link in the Prairie Chicken life chain" (Olson *in* preface to Hamerstrom and Hamerstrom 1973). Roberts (1936) postulated that the presence of grain for food was the stimulus for the westward and northwestward spread within the United States; the Greater Prairie-Chicken entered new areas soon after grain was planted. The importance of grains was corroborated by a 1962 study in Missouri, where 44% of diet volume was composed of corn, soybeans and sorghum, in descending order of importance, with wheat and oats together contributing another 9% (Korschgen 1962).

Macoun (1900) described it as a "true prairie bird as observers speak of it always being found in the open even in the severest weather." Everywhere it tended to choose low-lying areas with high grass. Schroeder and Robb (1993) point out that its preferred habitats tend to be interspersed with or surrounded by oak trees, reminiscent of the Passenger Pigeon (*Ectopistes migratorius*).

As it followed the plow westward, the Greater Prairie-Chicken presumably had the best of both worlds, but only for a short while. Long grass offered cover and grain fields provided food, the two habitats often "interdigitating" (Johnsgard and Wood 1968). They seemed to take advantage of the thick grass that grew luxuriantly between the time of lessened grazing pressure due to the demise of the Bison and the subsequent secondary over-hunting of Pronghorn (*Antilocapra americana*), and the later increase in cattle (graphed by Johnston and Smoliak 1976). The grassland range was "not fully stocked until about 1920." Suppression of grass fires by settlers was a further benefit.

Next, as even more land was cultivated, especially when cultivation reached 60% of the land area, and as ever-fewer parcels of grass interspersed with rosehips (Judd 1905) had sufficient area to support a group of prairie-chickens, this species left (Rue and Allen 1973). And, in the absence of fire, invasion of grasslands by trees and shrubs made grassland fragments even smaller. In North Dakota, the ideal habitat was grass 20 inches (50 cm) in height and sufficiently dense to completely conceal a nesting female; fields annually grazed, annually hayed, or idle >10 yr were undesirable (Kirsch 1973). In Oklahoma, Jones (1963) noted that mean height of vegetation in booming grounds was 15.1 cm., at nest sites 45 cm (range 25 to 70 cm), and escape cover, 60 cm.

The drought of the 1930s, complicated by overgrazing, sounded the final knell; few coveys could find luxuriant grass to provide adequate cover on the Canadian prairies. Between 1920 and 1940 there was also a slowly increasing shift from harvesting with threshing machines (producing attractive strawstacks) to combines (Svedarsky et al. 1997); the elimination of strawstacks was not complete until 1960, after the demise of the Greater Prairie-Chicken.

Decline in Alberta

In Alberta, Greater Prairie-Chickens had "practically disappeared" by the mid-1930s. The last sighting in the Drumheller area was by W.R. Salt north of Hand Hills, east of Drumheller, in 1925 (Kondla et al. 1973). They disappeared from the lek at the south end of Beaverhill Lake about 1929 (Farley 1932), except for a single in May 1932 and three seen there 24 May 1934 (Lister 1979).

Decline in Saskatchewan

In Saskatchewan, during the First World War all grouse numbers, including those of the Sharp-tailed Grouse and Ruffed Grouse, collapsed to such a degree that the season was closed for Sharp-tailed Grouse and Greater Prairie-Chicken from 1916 through 1920. Neil Gilmour, Game Guardian at Moose Jaw, reported in 1923 that the Sharp-tail and the Ruffed Grouse had rebounded and continued to increase, but the Pinnated, once fairly common, was

not coming back in numbers as the other two species had done (Bradshaw 1923).

The decline in Greater Prairie-Chicken numbers began early. They were common north of Bladworth until about 1918, with two booming hills of 12–15 birds each (Roy 1996). They were last observed booming on knolls near Langbank in 1924–1927 by Geoffrey Hewson (Belcher 1961; Hewson 1977), and last seen near Sheho about 1926 by William Niven (Houston 1949). They disappeared from the Storthoaks area by the late 1920s, certainly by 1935 (Stelfox 1980; Ray Barber, personal communication). Last "booming ground" at Cut Knife was in 1931, and the last in a hunter's bag at Maidstone was in 1932 (Symons 1967). Near Davidson and Imperial, Saskatchewan, they were "greatly decreased in numbers" by 1932, although there were still three booming grounds near Davidson and Stalwart and east of Imperial; two were seen at "Devil's lake" west of Simpson, and five specimens were collected at Last Mountain Lake (Todd 1947). They disappeared from the Qu'Appelle valley in the late 1930s (Callin 1980). The last observation at Raymore was of a single male observed by A. Cameron dancing with Sharp-tailed Grouse in the springs of 1947 and 1948 (Wayne C. Harris, unpublished manuscript).

There are only four known observations within the Saskatoon area. A mounted specimen in the possession of N. Loucks, Main Street, Saskatoon, had been collected about 1 February 1925 (interview with J. B. Gollop about 1970). A male specimen in the University of Saskatchewan Biology Museum, was collected at or near Saskatoon, 12 October 1931 (Smith 1968). From 1935 to 1945, Judge A. H. Bence (1945) observed the "odd covey" north of Saskatoon and he once watched the courtship "booming" display of the male near a slough between Borden and Radisson. In 1946, while collecting specimens for the Royal Ontario Museum, Farley Mowat (1946) flushed one near Dundurn, on the road to Proctor Lake, on 21 May [date obtained from Mowat's field notes].

We can only guess how common Greater Prairie-Chickens were in extreme southern Saskatchewan, but a few persisted until 1940 and 1941. Soper saw one or two every day at Rock Creek, south of Lafleche, on 7 and 8 June; one near Wood Mountain on 9 June 1940, and one along the Frenchman River below Val Marie on 16 June and one farther west at Middle Creek on 20 June 1941 (Soper 1970).

Probably Greater Prairie-Chickens were never common near the northern edge of their maximal range, though paradoxically this was where some of the final sightings occurred; here the requisite long grass persisted in clearings along the fringe of low-lying areas in mixed forest. The last sighting at Prince Albert was about 1932 (Brooman *in* Houston and Street 1959). Maurice Street or his brother Stanley saw a flock of nine, 8 km east of Nipawin, 10 December 1935. They were regular at Kelvington, Lintlaw and Somme until 1934, with the last sighting at Somme about 1942 (Hooper 1992). Several were seen along the west boundary road of Prince Albert National Park on 14 July 1940 in an area with small patches of prairie or grassy woodland glades ... a surprise (Soper 1952). James McCunn, on his farm a mile east of Codette, saw and shot his first on 20 September 1945. Two months later, on 20 November 1945, McCunn saw a flock feeding at a granary 43 km east of Nipawin (Houston and Street 1959). At Emma Lake, a flock of 12 in natural or "moose" meadows in 1937–38 decreased to three in 1939, the year that Mowat saw single individuals in Prince Albert National Park and at Montreal Lake (Mowat 1947). The last record in central Saskatchewan was of a lone bird 5 km north of Snowden, 10 June 1950 by Walter and Billy Matthews and three other observers (Houston and Street 1959).

In southern Saskatchewan, Soper's last sightings were one near Reed Lake, just south of Morse, on 16 July 1946. a pair near Redvers on 8 August 1946; two south of Bender post office, south of Whitewood, on 10 August 1946; and one near Red Jacket on 20 September 1947 (Soper 1970).

Decline in Manitoba

Having peaked in numbers, the decline was evident early at Birtle, Manitoba, where it was only "abundant until 1916" (Bird 1930). Bruce Noton (personal communication) remembers seeing two in the ditch en route to Royal School, 6 km west and 2 km north of Boissevain, about 1931; his friend, Herb Patterson, shot two south of Wawanesa in the early 1930s. In the winters of 1933 and 1934, Victor Latta reported a single bird near Shelley. T. Schindler shot his last one near Clandeboye about 1934 (Gardner 1981). G. W. Malaher saw over 300 within 100 km of Winnipeg as late as 1936 (Hamerstrom 1956). Douglas Shanks told of small numbers and at least one booming-ground near Old Pinawa in the late 1930s; his last sighting was of four in the same area in the winter of 1941–42 (Taylor 1983). The Greater Prairie-Chicken disappeared from Lyleton in the 1940s (Knapton 1979) and from the Oak Hammock Bog in 1946 (P. Romanic in Gardner 1981), but was present along the south edge of Delta Marsh "until 1950 when it declined rapidly." (Hochbaum 1971). Three were seen at Windfield Swamp near Stonewall by Robert E. Jones in the winter of 1950–51 (personal communication). John H. More saw a Pinnated Grouse with a group of Sharptails near Russell, on 8 October 1953 (letter, 19 October 1953).

Causes of decline

Bird (1961) ascribed the decline to two factors: over-shooting and destruction of nesting sites by intensified agriculture. A review article reported "It is ironic that the Greater Prairie-Chicken at first prospered from an expanding agriculture ... [until] the further development of cereal farming and cattle ranching eliminated the tall grass vegetation on which the species had depended....the late 1870s and early 1880s were wetter than normal and grass grew luxuriantly" (Johnston and Smoliak 1976). Godfrey (1986) summarized the situation similarly: "In the interim between the disappearance of the bison from the prairies (about 1880) and the beginning of intensive settlement (about 1920), the natural prairie grasslands flourished as never before and probably never will again. Natural grassland is ideal for the Greater Prairie-Chicken and it too flourished in that period and declined rapidly when its habitat was destroyed by the settlements of man."

Christisen (1969) has provided a list of factors detrimental to this species, with special reference to the United States: (a) conversion of grass to tilled crops, (b) removal of grass cover by grazing and haying, (c) overgrazing, (d) extensive burning, (e) loss of open grasslands to shrubs and trees, (f) drought in the 1930s, and (g) lack of winter food. Remaining populations in the 1960s were confined to areas with some Big Bluestem Grass, and in Missouri required areas with 25 to 30% grass. Another factor contributing to decline in Illinois was the decrease in production of redtop, *Agrostis alba*, which gave excellent nesting and brood cover, but was largely replaced by legume hays which were often harvested at the time when broods are hatching (Yeatter 1963). Depredations by raptors, an ever-present threat, seem not to have been a serious factor in the decline (Berger et al. 1963). Burning was not always detrimental; use of grassland *increased* the second year after a spring burn (Westemeier 1973).

Robel (1970) reported from Kansas that of 60 Greater Prairie-Chicken males on three booming grounds, 2.7 km apart, only 33 took up territory and only six (two at each booming ground) in any one year were involved in mating. Whether or not such social systems are dysfunctional in declining populations seems not to have been studied.

Skinner (1974) found that the two small colonies persisting in northern Missouri in 1973 had suffered mainly from conversion of grassland to cropland and intensive grazing on what pastures remained. Winter and summer, prairie-chickens preferred cover of 8 to 10 inches in height, hence Skinner suggested as a management technique for this species that the remaining "warm season grasses" should "never be grazed below ten inches"! Ryan et al. (1998) found that contiguous prairie > 65 ha supported a stable population over 27 years in southwestern Missouri, whereas nest success was lower in the prairie mosaic landscape and the population there declined.

Interbreeding/hybridization

None of the authorities quoted above mentioned hybridization as a contributing factor to the decline. However, hybridization with the Sharp-tailed Grouse (Evans 1966; Rowan 1926; Sparling 1980; Lumsden 1970), and less commonly with the Ring-necked Pheasant (Lincoln 1950), has had deleterious effects. On Manitoulin Island, Ontario, colonized by Sharp-tailed Grouse from the north, and by Greater Prairie-Chicken from the south (Lumsden 1949), hybridization seems to have led to the complete disappearance of the Greater Prairie-Chicken (Lumsden 1970; Godfrey 1986).

Grouse interbreed remarkably freely. Alberta's first two hybrids of Greater Prairie-Chicken with Sharp-tailed Grouse were reported from Gough Lake in 1918 and from near Edmonton in 1925 (Rowan 1926). C. G. Harrold (1933) identified two hybrids with a party of Sharptails near Old Wives Lake in May 1922, but Saskatchewan's first recorded hybrid specimen was not taken until 22 October 1933 by J. C. Lusted south of Regina at Truax (Belcher 1961). Some, perhaps most, of the last records of Greater Prairie-Chickens in the prairie provinces were in company with Sharp-tailed Grouse or Sage Grouse. At Raymore, Wayne C. Harris (personal communication) saw a hybrid Sharp-tailed Grouse × Greater Prairie-Chicken on 25 June and again on 24 December 1971. On 20 April 1987, Wayne C. Harris and Don Weidl saw a female Greater Prairie-Chicken on a Sage Grouse dancing ground between Killdeer and Val Marie in the west block of the nascent Grasslands National Park (Gollop 1987, Harris et al. 1987). Three days earlier they had seen what was hypothesized to be the first-ever hybrid Sage Grouse × Greater Prairie-Chicken. However, Dale Hjertaas (1995) photographed a Sage Grouse × Sharp-tailed Grouse hybrid south and west of Lafleche in May 1988, a hybrid similar in appearance to that reported earlier by Harris farther south. Similar hybrids have been reported from Montana (Eng 1973) and Alberta, with DNA analyses as proof for the latter (Aldridge et al. 2001). No Sage Grouse X Greater Prairie-Chicken hybrid specimen has yet been collected, probably due to the minimal overlap in their distribution.

In Nebraska, extensive surveys in the 1960s showed that up to 17% of display grounds were mixed, and that the minimum rate of Greater Prairie-Chicken hybridization varied from 0.3 to 1.2% (Johnsgard and Wood 1968). In extreme northwestern Minnesota, 3 of 11 stable display grounds were mixed, and up to 3.5% of the birds were hybrids (Sparling 1980).

We have no evidence incriminating the introduced Ring-necked Pheasant (*Phasianus colchicus*) with the decline of the Greater Prairie-Chicken in Canada. Widespread release of pheasants from the Beaver Creek Pheasant Farm south of Saskatoon, Saskatchewan, began only in 1946, *after* the demise of the prairie chicken. In Illinois, the relationship is more compelling: "the closure of hunting seasons on Greater Prairie-Chickens coincided with the initiation and expansion of pheasant stocking programs. ...remnant flocks exist outside the contiguous range of the pheasant." Further, parasitism of prairie chicken nests by hen pheasants was observed each year and parasitized nests were less successful than non-parasitized nests. With mixed clutches the pheasants hatched a day earlier, and the prairie chicken hen would leave "with the parasitic brood before her own eggs hatched." A single cock pheasant would dominate the entire booming ground. Removal of the offending cock merely allowed a subordinate successor pheasant to assume the same territory (Vance and Westemeier 1979).

In-breeding of isolated remnants on the Canadian prairies may have administered the final *coup de grâce*. In Illinois, Greater Prairie-Chicken numbers declined from several million birds in the mid-19th century (600 000 were marketed in Chicago in 1873; Westemeier and Edwards 1987), to a small remnant of 46 survivors by 1994. The dramatic crash in numbers is depicted on four maps; extremely low fertility and egg success of these isolated survivors was attributed to isolation and inbreeding, substantiated by a quick recovery of fertility and hatching success after 271 individuals had been introduced from large populations in three other states (Westemeier et al. 1998).

Last Alberta specimens

Shot 1931 between Czar and Hughenden (Mitchell 1959).

Shot 1938 near Youngstown (Salt and Wilk 1958).

Last Alberta sightings

Mid-1930s, near the Oldman River west of Fort Macleod (Mitchell 1959).

28 August 1939, two just outside Waterton Lakes National Park, not far from the Montana border (C. H. D. Clarke *in* Rand 1948).

1939, early 1950s, and finally in either 1961 or 1962, near Sullivan Lake (Mitchell 1959, Moyles 1987).

1940, north of Medicine Hat (Mitchell 1959; Godfrey 1966, 1986).

Through 1943, but not in 1944, Dick Beddoes had them in his unpublished Christmas bird counts at Daysland, southeast of Camrose (Beddoes 1945).

On 14 September 1965, B.R. Shantz (1966) saw eight birds, 13 km west of Coutts, Alberta, and only 3 km north of the Montana boundary, but Sadler and Myres (1976) categorized this as "questionable."

5 March 1972, a single bird near Mountain View, southwest of Cardston (Salt and Salt 1976).

Last Saskatchewan specimens

Shot 30 April 1931 at Imperial Beach by F.G. Bard (Belcher 1961);

Shot October 1931 by Dr. J.R. Hoag at Viewfield, northwest of Estevan (Belcher 1961);

Shot 24 Oct 1940 east of Simpson by F.G. Bard (Belcher 1961);

Shot fall of 1942, west of Saltcoats, by Robert Cock (Houston 1949);

Shot Oct 1943 at Marienthal, southwest of Estevan, by F.N. Dunk (Belcher 1961);

Shot 31 Oct 1945 near Carlyle, by R.J. Fyfe (Lahrman 1957);

Shot 3 Nov 1972 near Leader (Hatch 1973).

Last Manitoba specimens

Shot in 1957 at Delta Marsh, in the largest remnant of true tall-grass prairie, by a group of American hunters (Lawrence St. Goddard, personal communication, *fide* Robert E. Jones).

Shot in the fall of 1961 near Langruth (Salt and Salt 1976; Godfrey 1966).

Last Manitoba sightings

1972, a possible sighting in the Broomhill Wildlife Management area in southwest Manitoba (Vere Hunt Scott, *fide* Knapton 1979).

3 October 1978, Oak Hammock Marsh, Mr. McKillop (Gardner 1981).

1983, Spruce Woods east of Brandon, possible sight record by K. Leavesly (Minish 1987b).

25 May 1986, four near Pilot Mound, observed by Doug and Burton Collins (possibly escapes from releases made at Grand Forks, North Dakota, near the same time; Robert E. Jones, personal communication)

Last Saskatchewan sight records

Five unpublished Saskatchewan records resulted from my 1956 appeal, including the report of Rayner (and More's from extreme western Manitoba), above. Melvin Adair (letter, 12 March 1956), east of Outram, 18 km west of Estevan, believed that Ring-necked Pheasants, Sharp-tailed Grouse and Greater Prairie-Chicken all suffered severely in the blizzard of 1948. When in the spring of 1949 he dug out his coyote traps from beneath the melting drifts that had been 7.6 m deep, he found the corpses of a covey of Pinnated Grouse that had perished in that snowdrift. His Ring-necked Pheasant count locally dropped from 169 to 1, presumably the result of the same storm, reputed to have been the worst since 1888.

Peter McLellan of Arcola (letter, 24 March 1956) hunted Greater Prairie-Chickens in the Warmley area, 18 km north of Kisbey, until about 1936, about equal in numbers with Sharptails, and then saw a single individual there about 1946. His brother, J. S. McLellan, found them regularly in section 31-8-4w2, 6 km north and 3 km west of Arcola, but a careful search revealed none there in 1955, the year that Peter found three young closer to Arcola.

Four southern Saskatchewan sightings were near lakes. Near Lucky Lake, the last sightings of individual birds were on 15 August 1943 and 16 August 1947 (Roy 1996). Five were seen at Good Spirit Lake, 17 January 1946 by J. A. Gunn ("jottings" given to the late Mrs. Isabel Priestly, now in possession of CSH). Three birds were seen on the Otthon flats, southwest of Yorkton, early November 1946, by W. D. Lightbody (Houston 1949). J. E. Glennie found them northwest of Govan, within a mile of the east shore of Last Mountain Lake, about 1950 and 1951 (letter, 21 May 1956).

Farther south, David MacDonald of Manor saw one in the spring of 1954, three in 1958 and one at a Sharp-tailed Grouse dancing ground in the spring of 1959 (Belcher 1961). Fred Sharp saw three with eight Sharp-tailed Grouse, 6 km north of Sidewood in September 1959 (Belcher 1961). Roger Tory Peterson and James Fisher, arguably the two best-known ornithologists attending the American Ornithologists' Union meeting in Regina in 1959, saw a single cock Greater Prairie-Chicken within a mile of the east edge of Old Wives Lake on 25 August 1959 (Peterson 1960). Two were observed carefully near a highway near Stoughton in the fall of 1960 (Pringle 1961). Five were carefully described near the east edge of Old Wives Lake on 3 September 1961 (Pratt 1967). One was seen by J. Luthi, 5 km north and 13 km west of Simpson on 12 May 1962 (Luthi 1963). Twelve appeared on the farm of Gilbert Johnson near Marchwell on 16 February 1967 (Johnson 1967). A single individual was with six Sharptails near Ruthilda, mid-July 1971 (Wapple 1977). A hybrid was seen by Wayne C. Harris near Raymore, 25 June and 24 December 1971 (Houston 1971, 1972). Single birds were seen near Mortlach on 19 December 1971 and near Caron on 16 April 1972 (Brazier 1972a, 1972b). David W. Robinson saw two with Sharptails near Avonlea, 20 September 1975 (Serr 1976). Derek Kreuger saw two in the ungrazed section of the northeast quarter of Saskatchewan Landing Provincial Park in 1977 and again in 1978 (Blood and Anweiler 1979).

Hjertaas et al. (1993) collected additional observations for the RENEW report as follows: R. K. Brace, a biologist with Canadian Wildlife Service, saw one southwest of Lafleche about the summer of 1966. B. Campbell saw one on a Sharp-tailed Grouse lek 18 km south and 13 km east of Mortlach in April 1968. Don Jackson saw one 12 km north and 4 km east of Plunkett in October–November 1972. J. B. O'Neil saw one on a roadside 5 km east of Viscount in February 1973 and then saw a small flock on three consecutive Fridays 7 km east of Plunkett in February 1975. Gerhard Stuewe saw a group of between six and eight at Teo Lake, west of Kindersley, in mid-September 1975. Ross Campbell, a hunter, saw one and then three others within 8 km of the South Saskatchewan River, south of Riverhurst in Game Management Zone 26C in the fall of 1983, and then two near Floral in the winter of 1984–85 through 22 Feb 1985 (Hjertaas et al. 1993).

Wayne C. Harris saw a female Greater Prairie-Chicken in the west block of the National Grassland Park (34-2-12w3) on 20 April 1987 (already mentioned under "Interbreeding/hybridization, above). Then on 8 May 1987, Harris saw three Greater Prairie-Chicken males on the United States boundary just west of the west margin of the east block of the park (5-1-7w3); they flushed from an upland area and flew into Valley County, Montana, a region lacking either historic or recent records of Greater Prairie-Chicken. This was the third last report from Saskatchewan.

The second last sighting of probable Greater Prairie-Chickens in Saskatchewan were convincingly described north of Big Muddy by Carol Bjorklund, 28 July 1991 (Koes and Taylor 1991). Near the solitary male were three Sharp-tailed Grouse hens with broods (Carol Bjorklund, personal communication). Doris Silcox saw a single individual, together with 25 Sharptails and up to 9 Gray Partridge (*Perdix perdix*) at Carlyle, mid December 1991 through 18 Feb 1992 (Koes and Taylor 1992); this was the final sighting recorded for Saskatchewan and the last for Canada. One cannot but wonder how the individuals sighted above escaped detection in so many localities for so long without being seen, unless they fly long distances from the nearest stable groupings in the Dakotas. Should that be the explanation, then more sightings may occur in future, though without appreciable hope of re-establishment anywhere in the Canadian west. Indeed, the Greater Prairie-Chicken recovery team was disbanded in 1994. The species had been listed in Canada as Endangered in 1978, and then as officially Extirpated in 1990 (Hjertaas 1998).

Maps of range

The original zone of overlap between the Greater Prairie-Chicken and the Sharp-tailed Grouse was initially narrow (Figure 3 in Johnsgard and Wood 1968), but as the Greater Prairie-Chicken spread westward this zone of overlap greatly enlarged. By January 1955, Aldrich and Duvall (1955) showed habitat still occupied by Greater Prairie-Chicken in southern Manitoba, but none anywhere in

Saskatchewan, and only a small remnant area left in central Alberta. By 1979, Westemeier's map showed substantial populations persisting only in South Dakota, Nebraska, Kansas and Oklahoma.

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The following 34 curators responded to mail and e-mail requests, supplying data re egg sets:

Tim Armstrong, Adams State College, Alamosa, CO (ASC); Emanuel Levine, American Museum of Natural History, New York (AMNH); Ann Kessen, Bell Museum of Natural History, Minneapolis (BMNH); Karen Cebra, California Academy of Sciences, San Francisco (CAS); Will Post, Charleston Museum, Charleston, S.C. (CM); Starla Miller, Clemson University (CU); Tim Matson, Cleveland Museum of Natural History, Cleveland, OH (CMNH); Gene K. Hess, Delaware Museum of Natural History (DMNH); Kirstie M. Bay, Denver Museum of Natural History (DM); John Iverson, Joseph Moore Museum of Natural History, Earlham College, Richmond, Indiana (Earlham); Tom Webber, Florida Museum of Natural History, Gainesville (FMG); David Willard, Field Museum of Natural History, Chicago (FMNH); Tamar Danufsky, Wildlife Department Museum, Humboldt State University, Arcata, California (HSU); Nathan Kraucanus, Milwaukee Public Museum (MPM); Allen J. Kihm and Rand Rodewald, Minot State University (Minot); Alison Pirie and Raymond A. Paynter, Jr., Museum of Comparative Zoology, Harvard University (MCZ); Carla Cicero, Museum of Vertebrate Zoology, University of California Berkeley (MVZ); Michel Gosselin, National Museum of Canada, Ottawa (NMC) [now Canadian Museum of Nature]; Joseph Bopp, New York State Museum, Albany (NYSM); Gary D. Schnell, Oklahoma Museum of Natural History, Norman, OK (OMNH); John M. Condit, Ohio State University Museum of Biological Diversity, Columbus (OSUM); Fred C. Sibley, Peabody Museum, Yale University, New Haven (PMYU); Jocelyn Hudon and W. Bruce McGillivray, Provincial Museum of Alberta, Edmonton (PMA); Selma Glasscock, Rob and Bessie Wilder Wildlife Foundation, Sinton, Texas (RBWWF); Ross James, Royal Ontario Museum, Toronto (ROM); the late Bob Kreba, Royal Saskatchewan Museum, Regina (RSM); Robert McKernan, San Bernardino County Museum (SBCM); Krista A. Fahy, Santa Barbara Museum of Natural History (SBMNH); Philip Unit, San Diego Natural History Museum (SDNHM); Nancy Glover McCartney, University of Arkansas Museum (UAM); Katherine L. Doyle, University of Massachusetts, Amherst (UMA); Janet Hinshaw, University of Michigan Museum of Zoology, Ann Arbor (UMMZ); Alan Gubanich, University of Nevada, Reno (UNR); William J. Maher, University of Saskatchewan (USask); Thomas C. Erdman, University of Wisconsin, Green Bay (UWGB); Frieda Kinoshita, Western Foundation of Vertebrate Zoology (WFVZ), Los Angeles, since moved to Camarillo.

The following 16 institutions had egg sets of this species, but none from the Northern Great Plains: Clayton White, Brigham Young University, Provo, Utah; Arthur R. Clark, Buffalo Museum of Science, Buffalo, New York; Mary Hennen, Chicago Academy of Sciences, Chicago, Illinois; Jane E. Deisler-Seno, Corpus Christi Museum of Science and History, Corpus Christi, Texas; Christine Adkins, Cowan Vertebrate Museum, University of British Columbia, Vancouver; Steven D. Bailey, Illinois Natural History Survey, Urbana, Illinois; Kerri Leedy, Oakes Museum of Natural History, Messiah College, Grantham, Pennsylvania; Mark B. Robbins, Natural History Museum, University of Kansas, Lawrence, Kansas; Thomas E. Labedz, University of Nebraska, Lincoln, Nebraska; Albert G. Mehring, State Museum of Pennsylvania, Harrisburg, Pennsylvania; Janice Hall, Putnam Museum, Davenport, Iowa; David Denton and

Roseanna Humphrey, University of Colorado Museum, Boulder, Colorado; Gary Shugart, University of Puget Sound, Tacoma, Washington; Edward Marks, Museum of Natural History, University of Wisconsin Stevens Point, Wisconsin. Louis Levene, Cumberland Science Museum, Nashville, Tennessee; reported that their one North Dakota set had been de-accessioned to the Western Foundation of Vertebrate Zoology. Diane Fell reported that the Oklahoma Zoo no longer has an egg collection.

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Status of Common Eiders, *Somateria mollissima*, Nesting in the Digges Sound Region, Nunavut

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There is little information available on status of Common Eider, *Somateria mollissima*, populations nesting in Arctic Canada. We surveyed Common Eiders in the Digges Sound region, Nunavut, on 19–20 July 1999, for comparison with similar surveys in 1980–1983. On six islands for which data were available in both periods, there were 4–5 times as many nests in 1999 as in the early 1980s. The mean clutch size late in incubation in 1999 (3.3 eggs per nest) was similar to that in 1983 (3.2 eggs), but lower than in 1982 (3.9 eggs); timing of hatching was similar in the two periods. All three females caught during incubation were of the subspecies *S. m. borealis*. In contrast to Common Eiders *S. m. sedentaria* nesting in the Belcher Islands, Common Eiders nesting in the Digges Sound region appear to be faring well.

Key Words: Common Eider *Somateria mollissima*, clutch size, Digges Sound, egg size, populations, timing of hatching.

Common Eiders, *Somateria mollissima*, are an important subsistence and cultural resource for Inuit people in Canada's eastern Arctic, in additon to being important components of arctic marine ecosystems (Reed 1986). Despite this, there is little information available on status and trends of arctic-nesting Common Eider populations. Historical data exist for only a few locations in eastern Arctic Canada: the Belcher Islands and nearby Québec coast (Nakashima and Murray 1988), Ungava Bay (Chapdelaine et al. 1986), the West Foxe Islands (Cooch 1977; Cooch 1986), the Hell's Gate-Cardigan Strait region (Prach et al. 1986), and the Digges Sound region (Gaston et al. 1985). There is evidence that Common Eider, *S. m. sedentaria,* populations nesting in the Belcher Islands have declined sharply (Robertson and Gilchrist 1998). There also is evidence of long-term declines in *S. m.* v-*nigra* populations of northern Alaska and the western Canadian arctic (Suydam et al. 2000). Updated information on other populations is urgently required in order to assess their status and devise effective conservation strategies (compare Reed and Erskine 1986; Dickson 1997).

We counted Common Eider nests on six islands in the Digges Sound region, Nunavut, on 19–20 July 1999. Lying at the western end of Hudson Strait, Digges Sound appears to be near the southern limit of the breeding range of the migratory *S. m. borealis* subspecies, and near the northern limit of the breeding range of the non-migratory *S. m. sedentaria* subspecies (Abraham and Finney 1986). Common Eiders are an important source of meat, eggs, and down for people from the community of Ivujivik, Québec, which lies in the heart of the region (Gaston et al. 1985). In this paper, we report the results of our 1999 surveys and make comparisons with observations from 1980–1983, to assess the status of the Common Eider population nesting in this region.

Study Area

The Digges Sound region, and its seabird community, was described in detail by Gaston et al. (1985; see Figure 1). It is dominated by a very large aggregation (300 000 pairs) of Thick-billed Murres, *Uria lomvia*, that breed on the tall cliffs of East Digges Island and the Québec mainland south and west of Cape Wolstenholme. There are also many small, low-lying islands that support nesting colonies of Common Eiders and other marine birds. Potential predators on Common Eider eggs and ducklings that we saw on these small islands included Herring Gulls, *Larus argentatus*, Glaucous Gulls, *L. hyperboreus*, and Great Black-backed Gulls, *L. marinus.* The former two species breed in colonies throughout Digges Sound (note that there were ≥ 31 adult Glaucous Gulls with ≥ 6 ca. 15 to 20 day old young on South Skerry #3 on 19 July in 1999; this colony was not reported in Gaston et al. 1985). Only one Great Black-backed Gull, a first-summer bird, was seen in the Digges Sound region during 1980–1983, but there were three adult-plumaged birds near South Skerry #1 on 19 July in 1999; we saw no sign of breeding. There was no evidence of predation by Arctic Foxes, *Alopex lagopus,* on any islands that we visited. A single Polar Bear, *Ursus maritimus,* was present in Digges Sound in mid-July in 1999, but we

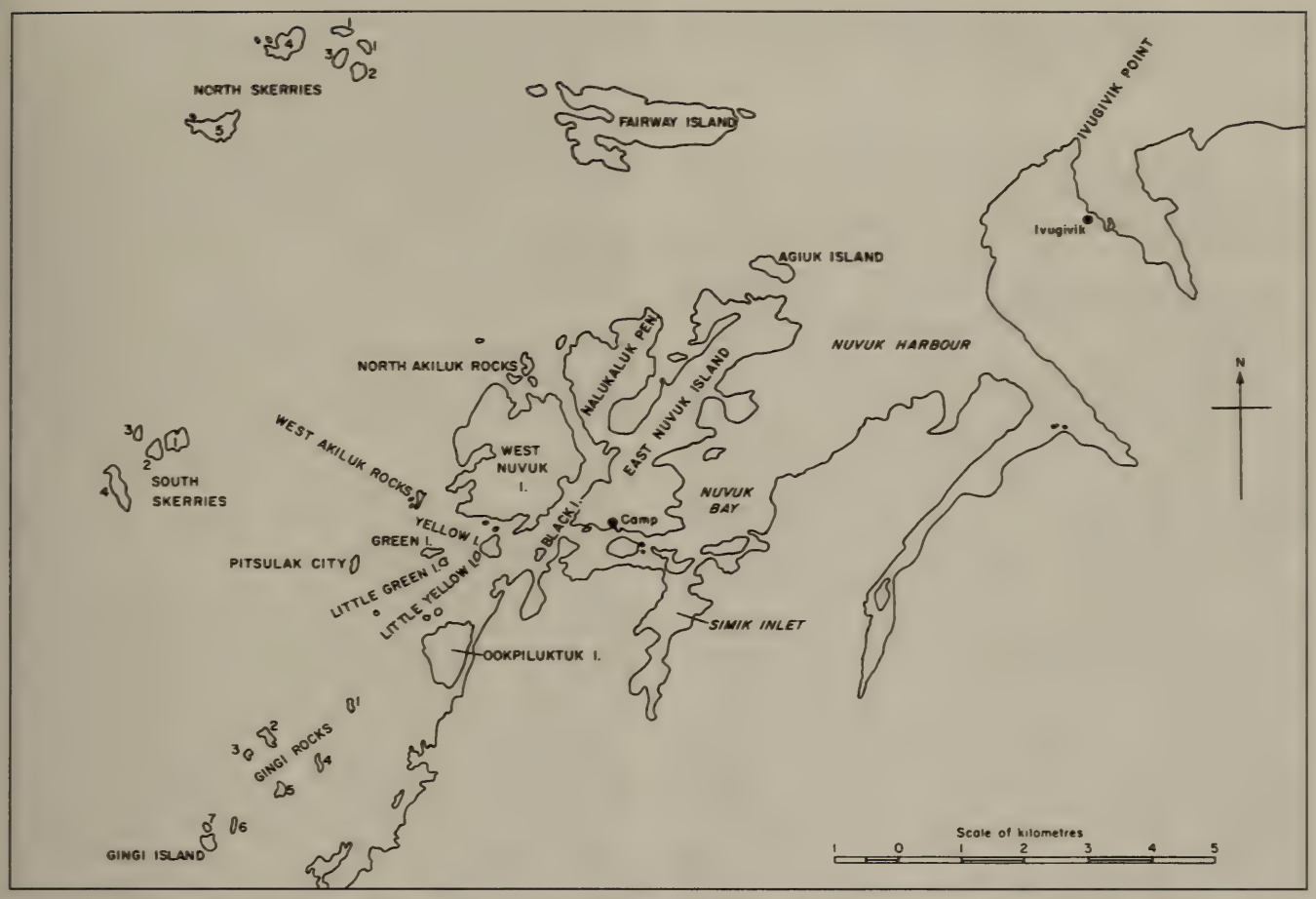

Figure 1. Map of the southern Digges Sound region showing the islands that were surveyed for Common Eiders in 1999.

saw nothing to suggest that it had been on any islands that we visited.

Methods

We surveyed six islands in the Nuvuk Islands region on 19 July 1999, including some of those on which the highest numbers of nests were found during surveys in the 1980s (in particular, the South Skerries; see Table 1, Figure 1). Results of our surveys should be comparable to those in the 1980s, because similar techniques were used; the one exception was that the number of nests was only estimated, not counted, on South Skerry #1 in 1981 (see Table 1). In 1999, each island was surveyed on foot by a crew of 3 who walked 5 m apart. As the islands were too large to be covered in one sweep, the crew member at the outside of the line marked the extent of each pass with rocks. The crew then turned around and returned, counting nests on the opposite side of the line. In this manner, islands were completely surveyed with little risk of nests being missed or counted more than once. A nest was counted if it had a well-defined cup with down; in this region, down is placed in the nest bowl after laying has been initiated (H. G. Gilchrist unpublished), so that downy nest cups without eggs represent nesting attempts that have failed. When a nest was found, its contents (e.g., empty, two eggs, three eggs and one duckling, etc.) were called out to one crew member who recorded the information. We thus obtained information on clutch sizes, and a crude indication of the timing of hatching. We also measured the length and maximum breadth of 100 eggs in 36 clutches.

We attempted to survey island groups to the north on 20 July, but rough seas and thick fog hampered our efforts. We returned to South Skerry #1 late in the afternoon on 20 July, in order to catch adult eiders. Bill measurements and blood samples were

TABLE 1. Common Eider nest counts in the Digges Sound region in different years.

	Year		
Island	1981	1983	1999[1]
South Skerry #1	75[2]	42	326 (255)
South Skerry #2	–	19	66 (48)
Pitsulak City	3	–	2 (2)
Green	4	20	25 (24)
Yellow	1	–	2 (2)
Black	0	–	0

[1]Counts in 1999 are: total nests with well-defined cups (total nests with ≥1 egg/duckling); no such distinction was made on counts in 1981 or 1983.
[2]Estimate only, no systematic count was made.

taken to determine the subspecific status of these birds (see Mendall 1986).

Results

We caught three incubating female Common Eiders on South Skerry #1 on 20 July. Bill measurements indicated that all three were of the subspecies *S. m. borealis* (cf. Table 1 in Mendall 1986): frontal extensions ranged from 13.2 to 16.3 mm, nostril extensions 25.7 to 31.0 mm, and total bill lengths 63.2 to 66.6 mm.

On the six islands we surveyed in 1999, we counted 421 nests with well-defined cups, of which 331 had at least one egg/duckling (Table 1). Our total count in 1999 was about 4-5 times higher than counts on the same six islands in the early 1980s (Table 1). Note that the count of 158 nests (range: 143–181) reported for the South Skerries in Gaston et al. (1985) was for all four of these islands, with the highest count from South Skerry #4 (73 nests). We did not do counts on South Skerry #3 or #4 in 1999.

In nests with at least one egg/duckling on South Skerry #1, South Skerry #2, and Green Island (n = 327; Table 1), clutch sizes late in incubation ranged up to 6 eggs, with a mean of 3.33 ± 1.03 (SD) eggs per nest. Common Eider clutch sizes varied among years in the Digges Sound region (ANOVA, $F_{2, 442} = 7.53$, $P < 0.001$). Tukey's tests (at the $a = 0.05$ significance level) indicated that the mean clutch size in 1999 was similar to that in 59 nests on the same three islands late in incubation in 1983 (3.20 ± 1.13), but smaller than that in 59 nests late in incubation on Eider Island and the North Skerries in 1982 (3.86 ± 1.09). The mean clutch size in 1999 was similar to that reported for *S. m. borealis* populations elsewhere in Canada (means of 2.72–3.52 eggs; cf. Table 3 in Prach et al. 1986).

At least one duckling was present in 0.9% of active nests (n = 331) found on 19 July, all of them on South Skerry #1 and #2. We also saw five broods on the sea off South Skerry #1 on this date, with 2–5 ducklings per brood. These observations suggest that hatching began about 17 July 1999, similar to the timing in the early 1980s: Common Eider ducklings were first seen on 17 July 1980, 21 July 1981, 14 July 1982, and 20 July 1983.

For 100 eggs from 36 entire clutches measured on South Skerry #1, Green Island, and Pitsulak City, the mean length was 75.4 ± 2.7 (SD) mm (range: 68.5–82.8 mm), and the mean breadth 49.3 ± 1.3 (SD) mm (range: 46.8–53.3 mm). Eggs were not measured on surveys in the early 1980s, but Common Eider eggs in the Digges Sound region in 1999 were similar in size to those laid by *S. m. borealis* elsewhere in Canada (mean lengths: 74.0 ± 3.3 to 75.8 ± 3.3 mm; mean breadths: 49.6 ± 1.7 to 49.7 ± 1.4 mm; cf. Table 2 in Prach et al. 1986).

Discussion

The total number of Common Eider nests that we counted on six islands in the Digges Sound region in 1999 was about 4–5 times the number counted on the same six islands in the early 1980s. It can be difficult to interpret the results of surveys such as these (Robertson and Gilchrist 1998). Many Common Eiders may forego breeding in years when environmental conditions are unfavourable (Coulson 1984), and as a result, low nest counts in such years could be wrongly interpreted as being indicative of population declines. Similarly, surveys that detect more nests, as did ours, could be wrongly interpreted as indicating population increases if the original surveys were carried out in unfavourable years with extensive non-breeding. While the latter is possible, we do not believe that this was the case here.

For Common Eiders, breeding parameters such as egg size, clutch size, and the timing of laying are sensitive to variation in environmental conditions during the pre-laying period (Robertson 1995). Egg and clutch sizes that we measured were very similar to those reported for Common Eiders elsewhere in the eastern Canadian arctic, and clutch sizes were similar to, or smaller than, those in the Digges Sound region in the early 1980s. Moreover, the timing of hatching and dates of observations of first broods appeared to be very similar during the two survey periods. Collectively, these results suggest that it is unlikely that conditions were so poor that only low proportions of eiders bred in all years when surveys were carried out in the early 1980s. Given that survey techniques were similar in the two time periods, involving counts of all active and failed nests, we conclude that the substantial increase in the number of Common Eider nests in the Digges Sound region probably reflects an actual increase in the size of the local breeding population.

If so, this raises two important questions. First, what factors might have caused the increases in the numbers of Common Eiders nesting in this region since the early 1980s? And second, if real, are increases in this region indicative of increases in Common Eider *S. m. borealis* populations elsewhere in eastern Arctic Canada?

We do not have definitive answers to either question. Given that there were no obvious differences in environmental conditions between the two survey periods, the dramatic increases that we detected may have been due to lower levels of local human exploitation than occurred previously. Common Eider populations in the Foxe Islands declined dramatically between 1956 and 1976, apparently due to local harvesting practices. Many eider colonies in that region are easily reached by hunters traveling by boat from Cape Dorset, and the subsistence harvest of eggs, and especially the shooting of females, had dramatic effects on the population (Cooch 1986). It

may be noteworthy that the largest increases in the number of Common Eider nests in the Digges Sound region occurred on the South Skerries. These islands are off the regular travel routes, and rarely are visited by people from Ivujivik (Gaston et al. 1985). As a result, they may function as safe nesting refuges during times when few people are venturing out specifically to harvest eiders or their eggs. Unfortunately, no data exist to allow us to directly examine the possibility that the apparent increase was due to lower local harvests of Common Eiders, or eider products, in recent years. We also have no information with which to assess the role that immigration from local or more distant colonies might have played.

Might the apparent increases that we detected in Common Eider populations in the Digges Sound region reflect increases elsewhere? Although populations of *S. m. sedentaria* appear to have declined considerably in the Belcher Islands, an island group to the south of Digges Sound, this was probably due to severe ice conditions in Hudson Bay that caused high overwinter adult mortality in this non-migratory subspecies during the early 1990s (Robertson and Gilchrist 1998). Causes of declines in populations of *S. m.* v-*nigra* in northern Alaska and the western Canadian arctic are unknown (Suydam et al. 2000).

It is both costly and logistically difficult to conduct surveys of Common Eiders at arctic colonies, and they cannot normally be carried out on a large geographic scale. Instead, small clusters of nesting islands are usually surveyed and the results cautiously extrapolated to the larger population (Cooch 1986). However, surveys conducted in regions where eiders have historically been, or are currently being, subjected to local subsistence harvests cannot reliably be extrapolated to non-harvested populations, because local anthropogenic effects could easily swamp large-scale environmental effects. Consequently, repeat surveys of colonies elsewhere are now required to assess trends in *S. m. borealis* populations in other areas. Given these considerations, it is apparent that an ideal monitoring scheme for Common Eiders would include both harvested and non-harvested populations. Although this would add substantially to the cost of monitoring programs, it should allow investigators to distinguish between the local effects of human harvesting and environmental effects that operate over a broader geographic scale. This would aid greatly in management.

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Flathead Chubs, *Platygobio gracilis*, in the Upper Missouri River: The Biology of a Species at Risk in an Endangered Habitat

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Flathead Chub, *Platygobio gracilis*, populations have declined in portions of their range where natural flood-pulses and functioning backwaters have been eliminated. Observations of these declines have led ecologists to consider both the species and their at-risk habitats. Backwater and sandbar habitats in the Missouri River, North Dakota were sampled during a high flow (1997) and an average flow (1999) year. Of the 817 larval fishes captured in the backwaters, none were Flathead Chubs. Significantly fewer ($P<0.01$) Flathead Chub adults and juveniles were captured in the backwaters than from sandbar habitats during all sample periods. Male chubs were all mature at 110-mm total length (TL) and age 2, whereas females were not all mature until age 3 and 170-mm TL. In 1997, Ostracoda, Hemiptera, and Copepoda dominated the diets, whereas in 1999, Coleoptera, Trichoptera, and Hymenoptera were utilized in significantly greater amounts ($P<0.05$). Flathead Chub maximum age was 5 and the mean back-calculated total lengths at age were 104-, 153-, 186-, and 223-mm TL for ages 1–4. Incremental growth analyses indicated that greater increases in total length were attained in 1997 than in 1999; however, body condition was significantly higher in 1999 ($P<0.006$). The contradiction between growth and condition cannot be explained; however, it could be energetically advantageous to maintain a more fusiform body shape during high flows. Although the backwaters were not important physical habitat for Flathead Chubs, backwater productivity may have critically contributed to the prey base during the high flow period of 1997.

Key Words: Flathead Chub, *Platygobio gracilis*, Cyprinidae, habitat alterations, food habits, Coleoptera, Copepoda, backwaters, Missouri River, North Dakota.

Cross et al. (1986) and Pfleiger and Grace (1987) reported that Flathead Chub, *Platygobio gracilis* Richardson, populations have decreased by as much as 98% over portions of their historical range. Grady and Milligan (1998) and Gelwicks et al. (1996) both observed Flathead Chub declines in the channelized and impounded segments of the Missouri River. These declines are not well understood; however, degraded habitats are a suspected cause (Lee et al. 1980). Researchers have correlated sensitive species declines with channel and flow modifications (Hesse et al. 1989). In addition to the problems of population loss and habitat modifications, Flathead Chub are difficult to study because their life history has not been thoroughly documented.

Fisher (1999) noted that a segment of the Missouri River in North Dakota contained Flathead Chubs and was maintaining historical habitat characteristics, including natural flood-pulse patterns from Yellowstone River inflow and a functioning lateral relationship with floodplain backwaters. Scott and Nielsen (1989) and Sabo and Kelso (1991) demonstrated that backwater habitats are important rearing and nursery areas for numerous native fishes. Additionally, Amoros (1991) suggested that floodplain flushing transports invertebrates from backwaters to the main channel, providing an important food resource for native fishes obligated to flowing water habitats. Eckblad et al. (1984) observed substantial increases in channel invertebrate densities below connection points with floodplain wetlands and Kennedy (1979) suggested that restricted backwater discharge may create invertebrate voids in the main channel. Therefore, understanding the relationships that Flathead Chub populations maintain with their habitats and food resources under varying water conditions may be critical.

The relatively unknown status and function of Flathead Chub populations in North American river systems remain a point of interest. Furthermore, opportunities to study Flathead Chubs and other native fishes in relatively unaltered habitats and hydrographs have become increasingly rare. Therefore, the objectives of this study were to (1) assess general Flathead Chub biology, including age and growth, food habits, habitat use, size structure, and maturation patterns, (2) contrast life history patterns between two years with substantially different hydrographs, and (3) assess and discuss the potential importance of backwater habitats to Flathead Chubs. This reference information from a stable Flathead Chub population in a healthy river stretch should help biologists evaluate populations in degraded lotic systems.

Study Area

The Missouri River study area lies between the Yellowstone River confluence and Lake Sakakawea in North Dakota (48°N, 103.9°W; river kilometers 2510–2518; river mile markers 1569–1574). This Missouri River stretch was selected because the unregulated Yellowstone River discharge provides a nearly historic flood-pulse hydrograph. Also within this stretch, several functioning backwater wetlands and numerous clusters of sandbar habitats are present. We monitored two backwaters and two sandbar complexes for use by Flathead Chubs. The two backwaters were described as off-channel habitats that connected to the Missouri River during one or more periods annually and maintained minimal flow (Fisher 1999). Surface areas for both backwaters were variable depending upon the prevailing hydrologic conditions; however, each was characterized by annual inundation of terrestrial vegetation, silt and mud dominated substrate, presence of marsh smartweed, *Polygonum coccineum*, and depths that generally did not exceed 1.5 m. The sandbar complexes were each located in close proximity to the outlet channels of the above-mentioned backwaters and also varied in extent and persistence due to hydrologic conditions. Although the location and extent of sandbars was dynamic, the habitat was dominated by sand substrates, tended to be free from woody or other vegetative debris, and ranged in depth from 0.2 to 2.0 m.

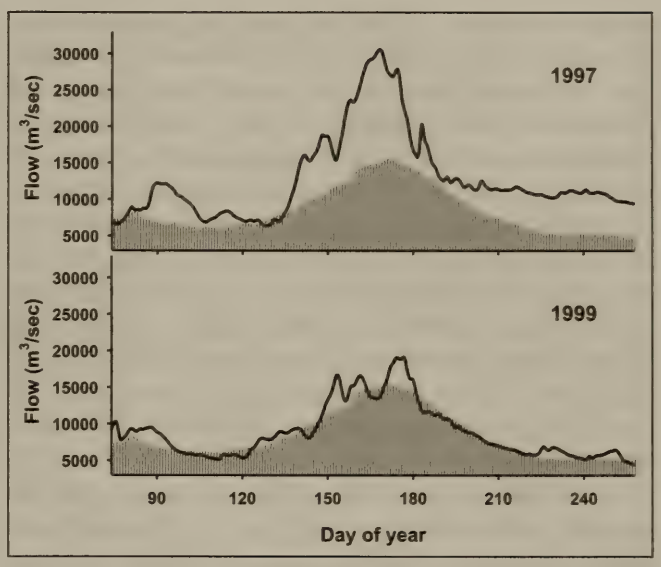

FIGURE 1. Cumulative daily flow (m^3/sec) for the Missouri River below the Yellowstone River confluence and above the Lake Sakakawea headwaters in North Dakota for calender days 75–260 of 1997 and 1999. The solid line represents the total sum of the flow estimates for gauging stations in the Missouri River and Yellowstone River upstream from the confluence. The shaded area represents the 40-year mean flow for the period 1959–1999.

Methods

Sampling Schedule and Habitat Analyses

To provide a distinct comparison, we sampled Flathead Chubs in the Missouri River during one hydrograph cycle that approximated mean flow (1999) and during another cycle that included substantially greater flow volume (1997; USGS 1999*; Figure 1). In 1997 and 1999, temperature, turbidity, and dissolved oxygen data were collected from channel-sandbar and backwater habitats. See Table 1 for sampling schedule information. We were unable to sample sandbars during sample period 2 in both 1997 and 1999 due to high waters from mountain snowmelt that inundated the habitat from mid-May through mid-June. Data were tested for normality with a Shapiro-Wilkes test (UNIVARIATE procedure; SAS 1990). Likely due to small sample size, not variance, none of these data sets were normally distributed; therefore, a nonparametric Kruskal-Wallis analysis of variance (AOV) by ranks (NPAR1WAY procedure; SAS 1990) was used to assess main effects. When a significant difference was detected, a Mann-Whitney U test (NPAR1WAY procedure; SAS 1990) was used to locate those differences. Statistical significance for these and all other analyses was set at $\alpha = 0.05$.

Fish Sampling and Analyses

Fish were collected during each sample period in the backwaters and from sandbar habitats with a bag seine (30-m long × 1.8-m high, 1.8-m^3 bag, 6-mm bar

TABLE 1. Sampling schedule used in 1997 and 1999 in the study area, including the Missouri River main channel (CH), sandbar complexes (SB), and associated backwaters (BW). Habitats sampled during each sample period are denoted with an X. Some data, due to high flows and minimal habitat presence, were not available (NA).

			Habitats Sampled		
Sample Period	Calender Days	Month	CH	SB	BW
1	114–120	April	X	X	X
2	139–145	May	X	NA	X
3	183–189	July	X	X	X
4	225–231	August	X	X	X
5	255–261	September	X	X	X

mesh). Six seine hauls were completed in each habitat type per sample period between 1000 and 1700 hours. The seine was pulled perpendicular to the backwater shorelines or with the current along sandbar margins for approximately 20 m and then arched to the shoreline. Captured fishes from the backwater samples were counted, measured to the nearest mm total length (TL), and released. Fishes captured during sandbar seining were also counted and measured; however, up to 30 Flathead Chubs from each of the following total length groups per sample period were euthanized and returned to the laboratory for biological analyses. The total length groups were < 60, 60–99, 100–139, 140–179, and > 179 mm.

The Flathead Chub relative abundance was expressed as number/seine haul and length-frequency histograms were created. Relative abundance data were tested for normality. Data not normally distributed were transformed [log10 (n+1)] and again tested for normality. The relative abundance data were found to not be normally distributed, even after transformation; therefore, we used a nonparametric Mann-Whitney U test on the untransformed data to assess the differences between habitat types among sample periods within each year. The same analysis was used to evaluate differences between habitats during each sample period between years. To provide additional samples for biological assessments in the two length groups exceeding 140-mm TL, a gill net (21-m long × 2-m high with one 7-m panel each of 1-, 2-, and 3-cm bar measure mesh) was drifted for short distances on the deeper portions (1.5–2.0 m) of the sandbar flats. Gill-net captured Flathead Chubs were added to samples for biological assessments; however, these data were not included in catch-per-unit-effort (CPUE) analyses.

To better assess the potential utility of backwaters as nursery and rearing habitats for Flathead Chubs during their early life history, larval fishes were collected with modified quatrefoil light traps (Floyd et al. 1984; 25-cm high × 30-cm wide with two 2-mm and two 4-mm slot openings). Ten randomly placed light trap sets were completed in each backwater during each sample period. Attempts to sample larvae in calm channel areas with the light traps failed due to physical trap damage and sedimentation. The light traps were deployed between 1600 and 1800 h and emptied prior to 1100 h the following day. Two 12-h photochemical light sticks were used as the light source in each light trap each night. Photochemical light stick intensity and light duration varies with temperature; however, Kissick (1993) found that photochemical sticks attract larvae for at least 1 h. All photochemical sticks used in this study were found to continue glowing up to 24 h after initial use; regardless, light sticks were replaced each night. Larval fishes were preserved in 5% formalin and returned to the laboratory for identification. Case specimens were sent to the Larval Fish Laboratory at Colorado State University for positive identification. Once identified, the specimens were enumerated and indexed as number/trap night.

General Biological Evaluation

In the laboratory, euthanized Flathead Chubs were again measured to the nearest mm TL and weighed to the nearest 0.1 g. Additionally, scales and otoliths were removed from September-sampled fish for age and growth analyses, stomachs were removed for a seasonal food habits assessment, and gonads of each fish were inspected to determine sex and maturity stage. Log10 transformed weight-length regressions were completed for each year and sample period (REG procedure; SAS 1990) and analyzed with an analysis of covariance (GLM procedure; SAS 1990) to determine if intercepts and slopes differed between years.

Age and Growth Assessment

We attempted to age the September-captured Flathead Chubs using both otoliths and scales. Scales were aged directly from a projected microfiche image. The focus, annuli, and radius data from each scale were digitized into the DISBCAL software program and mean length at age was determined using the Fraser-Lee method (Frie 1982). A regression analysis of scale radius on total Flathead Chub length was conducted within DISBCAL to determine the best available intercept, or a-value, for the back-calculations. Otoliths were prepared for reading using both vertical cross-sectioning and horizontal grinding to help expose the otolith circuli; however, the annuli were not discernable. Therefore, all of the age and growth analyses were based on scale annuli. Mean length at age for Flathead Chubs from both years combined was determined to provide a general description of growth at this geographic location.

To assess differences in growth between the high-flow year of 1997 and the mean-flow year of 1999, the mean growth increments for 2-cm TL Flathead Chub subgroups were determined for the first 258 days of each respective year. Martyn and Schmulbach (1978) suggested that annulus formation did not occur in Flathead Chubs until late May; therefore, the growth increment from the time of capture to the last annulus may only represent growth for 100–115 days. Using an AOV for unbalanced data sets, we completed a two-way AOV with year and length category as the main effects (GLM procedure; SAS 1990). The interaction term between the main effects was not statistically significant ($P = 0.156$); therefore, we completed a one-way AOV between years within each length category to determine if the Flathead Chubs accumulated total length at a greater rate in 1997 or 1999. We also completed an AOV among length categories within each year to determine if different length groups accumulated total length at significantly different rates. When a significant difference was detected,

we used a Tukey multiple-range test to identify those differences (TUKEY option in GLM procedure; SAS 1990).

Food Habits Assessment

Stomach contents from the euthanized Flathead Chubs were enumerated. Food habits were assessed for feeding uniformity by determining the frequency of occurrence, while feeding intensity on each prey type was investigated by determining the percent by number for each prey item within each Flathead Chub length group. Frequency of occurrence was the proportion of individuals in each Flathead Chub length group that contained the prey item. The percent by number for each prey item was determined for stomach contents for each fish that contained food and the mean values for each length group were reported. Bowen (1996) noted that proportional diet data are not normally distributed; therefore, a Mann-Whitney U test was used to detect significant proportional differences between years within each sample period and Flathead Chub length group. Because our objective was to assess food habit differences between different hydrologic conditions, no comparison among length groups within each year was completed.

Results and Discussion

Habitat Comparison

Channel habitat parameters, including temperature, dissolved oxygen, and turbidity were not significantly different ($P > 0.05$) from sandbar measurements in any collection period during either collection year (Table 2); therefore, the results and discussion will focus on the comparisons of backwaters with sandbar habitats only. Backwater and sandbar temperatures were more similar in 1997 than in 1999. Backwater temperatures in 1997 were 0.4 to 1.4°C warmer than the sandbar habitats, but were not significantly different during any months ($P > 0.05$). In 1999, backwater temperatures were significantly higher ($P < 0.05$) in all months by 1.8 to 4.5°C (Table 2). September was the only sample period in 1997 with significantly higher backwater dissolved oxygen levels ($P < 0.05$); whereas in 1999, July was the only sample period without significantly greater backwater dissolved oxygen concentrations. Turbidity levels were significantly lower ($P < 0.05$) in the backwaters during all sample periods in 1997 and 1999 (Table 2).

Sandbar habitat temperatures during the July and September sample periods of 1997 were significantly warmer ($P < 0.05$) than in 1999 by 1.6 to 1.7°C. In contrast, the backwaters were significantly cooler during May and September of 1997 ($P < 0.05$) than the same sample periods of 1999 by 4.1 and 2.4°C, respectively (Table 2). During July, August, and September of 1999 in both sandbar and backwater habitats, dissolved oxygen levels were significantly

TABLE 2. Mean temperature, dissolved oxygen, and turbidity data collected in the Missouri River, North Dakota, in 1997 and 1999. Data were collected at designated time periods in backwaters (BW), the main channel (CH), and near sandbar complexes (SB). Standard errors are noted in parentheses. The results of three separate statistical comparisons are described in this table. Within each year and month, the three habitats were compared and the statistical results are coded with the letters a, b, and c. Within each year and habitat type, the sample periods (months) are compared and the statistical results are coded with the letters m, n, o, and p. Within each habitat type and month, the 1997 and 1999 statistical comparison is coded with the letters x and y. Within each set of comparisons, means with the same letters were not statistically different ($P > 0.05$). Each mean was derived from five measurements.

	1997			1999		
Parameter/Period	BW	CH	SB	BW	CH	SB
Temperature (°C)						
April	amx11.7	amx11.2	amx11.3	amx12.6	bmx10.6	bmx10.8
May	anx14.2	amnx13.6	NA	any18.3	bny16.1	NA
July	aox22.8	apy21.3	aoy21.4	aox22.8	box19.4	box19.8
August	aox21.9	aox19.9	aox19.9	aox23.3	box19.8	box20.0
September	anx16.7	any16.0	any16.3	any19.1	bnx14.4	bnx14.6
Dissolved oxygen (mg/L)						
April	anx9.1 (0.3)	aox8.5 (0.2)	aox8.6 (0.3)	any9.4 (0.2)	bnx8.3 (0.1)	bmx8.5 (0.2)
May	any9.3 (0.3)	apy9.6 (0.2)	NA	amx7.8 (0.3)	bmx6.6 (0.1)	NA
July	amx7.0 (0.2)	amx6.7 (0.1)	amx6.8 (0.2)	amy8.4 (0.3)	any8.5 (0.1)	amy8.4 (0.2)
August	amx7.7 (0.3)	amnx7.2 (0.2)	amnx7.2 (0.3)	any9.3 (0.2)	bny8.3 (0.1)	bmy8.1 (0.2)
September	amx8.3 (0.1)	bnx7.7 (0.1)	bnx7.7 (0.1)	aoy11.0 (1.0)	boy9.2 (0.1)	bny9.3 (0.2)
Turbidity (NTU)						
April	anx66 (18)	bny94 (7)	bny99 (5)	anx46 (11)	bnx74 (9)	bnx82 (3)
May	amx17 (8)	bpy216 (24)	NA	anx33 (10)	bpx135 (2)	NA
July	amx16 (3)	boy156 (6)	boy160 (6)	amx10 (3)	box112 (3)	box116 (5)
August	amx14 (5)	bny85 (8)	bny89 (3)	amx8 (1)	bnx65 (3)	bnx72 (4)
September	amx11 (2)	bmx38 (5)	bmx39 (5)	amx9 (2)	bmx40 (3)	bmx39 (4)

higher than in 1997 ($P < 0.05$; Table 2). Turbidity levels were not significantly ($P > 0.05$) different in the backwater habitats between 1997 and 1999, even though sandbar turbidity levels were significantly higher ($P < 0.05$) in April, July, and August of 1997 (Table 2).

In 1997, the high flow created more floodplain connection points with longer duration. As a result, the 1997 temperature and dissolved oxygen levels in the backwaters were quite similar with those found in the channel. In 1999, these same variables operated more independently with less influence from channel connections (Table 2). Regardless of year, the backwaters maintained the ability to filter channel connection inflow and without exception, backwaters had significantly lower turbidity levels ($P < 0.01$; Table 2). This filtering capability, warmer water temperatures, an abundance of potential food resources such as zooplankton and benthic invertebrates (Fisher 1999), and more static conditions would appear to create conditions sought and preferred by some native fishes as nursery, rearing, feeding, and refuge habitats.

Fish Sampling

In 1997 and 1999 combined, 817 larval fish were captured in the light traps; however, none were verified as Flathead Chubs. Of these larvae, 70% were *Ictiobus* spp. (Buffalo fishes), 12% were Common Carp, *Cyprinus carpio*, and 8% were River Carpsucker, *Carpiodes carpio*. Additionally, only eight Flathead Chub juveniles and adults (>3-cm TL) were captured with the bag seine in the backwaters (Table 3). Significantly more Flathead Chubs, >12/seine haul, were captured in the sandbar habitats during all sample periods and both years ($P < 0.01$; Table 3).

Although greater numbers of Flathead Chubs were captured on sandbar habitats, there also existed several significant differences in mean CPUE among sample periods. During both years, greater numbers of Flathead Chubs could be sampled near sandbar complexes later in the year (Table 3). In addition to higher CPUE, more large Flathead Chubs, particularly those exceeding 16-cm TL, could be captured during August and September, with the greatest range in size structure occurring in September during both 1997 and 1999 (Figure 2).

Even though numerous larval fishes were sampled in the backwater habitats, no chubs of any genera were captured in the light traps. If the chub larvae were present, they were not sampled, possibly due to negative phototaxic habits or data collection timing problems. Likewise, the low CPUE indicated minimal presence of juvenile and adult Flathead Chubs in the backwater habitat. We hypothesized that high backwater connectivity to the channel would allow increased Flathead Chub use of the backwater habitats. Even in the presence of near record connectivity during 1997, Flathead Chub use of the backwaters as physical habitat was limited.

The increased presence of large (>16-cm TL) Flathead Chubs on the sandbars in the September samples (Figure 2) might suggest that the primary breeding adults stage, spawn, and recover in other channel habitats, as their conspicuous absence during the entire season except for the fall samples was easily noted. Peters and Holland (1994) found that all life stages of Flathead Chubs in the Platte River, Nebraska, utilized channel regions with sandy substrates and depths < 50 cm. The sandbar habitats appeared to be important feeding and rearing areas for juvenile Flathead Chubs during all sample periods. In addition, the age-0 Flathead Chubs, represented by newly recruited individuals <4-cm TL, appeared on the sandbar habitats in late summer and early fall. The observation of age-0 Flathead Chub using the sandbar complexes could be an important life history documentation.

Sexual Maturity

Gonadal assessment in September-captured Flathead Chubs revealed that some males began to exhibit maturing testes by 60-mm TL, but likely did

TABLE 3. Catch per unit effort for Flathead Chub captured with bag seines (number/seine haul) in two upper Missouri River backwaters (BW) and on two sandbar complexes (SB). The standard error of each mean is noted in parentheses. There are two sets of statistical comparisons denoted in this table. Within each habitat type and month, the letters a and b represent the comparisons between the 1997 and 1999 data points. Within each habitat and year (i.e., each column of means), the letters x and y represent the comparison among the five sample periods (months). For each set of comparisons, means with the same letters are not statistically different ($P > 0.05$). Each mean was derived from six measurements.

	1997		1999	
Sample period	BW	SB	BW	SB
April	^{ax}0.2 (0.1)	^{bx}12.3 (3.2)	^{ax}0.2 (0.1)	^{bx}18.7 (8.2)
May	^{x}0.2 (0.2)	NA	^{x}0.3 (0.2)	NA
July	^{ax}0.3 (0.2)	^{bxy}24.2 (3.1)	^{ax}0.2 (0.1)	^{bx}12.5 (6.3)
August	^{ax}0.0 (0.0)	^{by}37.0 (13.3)	^{ax}0.0 (0.0)	^{by}52.0 (11.5)
September	^{ax}0.0 (0.0)	^{bxy}29.2 (9.7)	^{ax}0.0 (0.0)	^{by}55.8 (22.5)

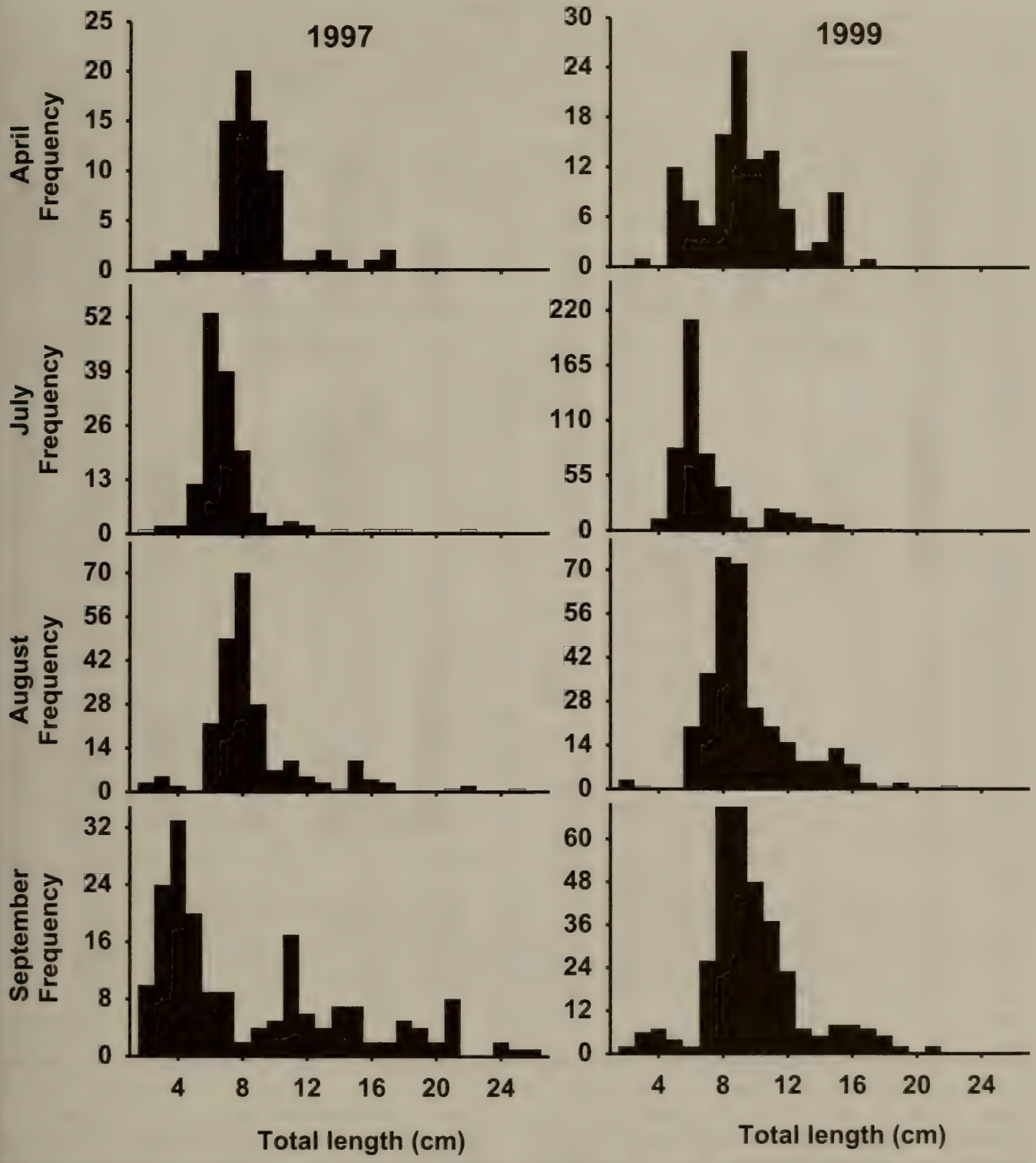

FIGURE 2. Length-frequency histograms of Flathead Chub captured from sandbar habitats in the Missouri River, North Dakota during four sample periods in 1997 and 1999. The frequencies represent the total catch from six seine hauls per sample period.

not spawn until the following season. Of male Flathead Chubs captured in April, 66% had developed testes at 75-mm TL. At 110-mm TL, 100% of male Flathead Chubs had reached sexual maturity. The smallest Flathead Chub that contained developed ovaries in April was 85-mm TL. Only 21% of the chubs that appeared to be female and were less than 125-mm TL contained mature eggs. By 155-mm TL, 80% of the female Flathead Chubs were mature, but not until 170-mm TL was 100% female sexual maturity noted.

Olund and Cross (1961) suggested that sexual maturity was attained by both sexes at about 85-mm standard length in Alberta, and Brown (1971) noted well-developed gonads in Flathead Chubs approximately 82-mm TL in Montana. Conversely, Gould (1985) found that the minimum total length for male and female maturation in the Musselshell River,

TABLE 4. Frequency of occurrence (%) for stomach contents of Flathead Chubs collected in 1997 and 1999 from sandbar habitats in the Missouri River, North Dakota. Sample periods, total number (N), and percent of empty stomachs (E) are noted. Food items included Ostracoda (OST), Diptera (DIP), Ephemeroptera (EPH), Hemiptera (HEM), Hymenoptera (HYM), Odonata (ODO), Orthoptera (ORT), Plecoptera (PLE), Trichoptera (TRI), Copepoda (COP), Coleoptera (COL), and macrophytes (MAC). Total length groups (TL; mm), included 1=<60, 2=60–99, 3=100–139, 4=140–179, and 5=>179. Absent groups imply that no specimens were collected.

Month	Year	Length	N	E	OST	DIP	EPH	HEM	HYM	ODO	ORT	PLE	TRI	COP	COL	MAC
April	97	1	8	0.0	100.0	12.5	0.0	25.0	0.0	0.0	0.0	0.0	12.5	50.0	0.0	0.0
April	99	1	13	0.0	16.4	23.1	0.0	0.0	7.7	0.0	0.0	0.0	0.0	15.4	92.3	0.0
April	97	2	30	46.7	36.7	26.7	0.0	20.0	0.0	3.3	0.0	0.0	16.7	26.7	0.0	0.0
April	99	2	30	13.3	3.3	40.0	3.3	9.9	0.0	0.0	0.0	13.3	3.3	3.3	76.7	0.0
April	97	3	13	0.0	69.2	30.8	0.0	30.8	0.0	30.8	0.0	0.0	53.8	38.5	0.0	0.0
April	99	3	29	10.3	6.9	55.2	3.4	10.3	17.2	17.2	0.0	13.8	27.6	3.4	72.4	0.0
April	97	4	4	0	25.0	50.0	0.0	0.0	0.0	25.0	25.0	0.0	75.0	75.0	0.0	0.0
April	99	4	10	0.0	0.0	20.0	20.0	40.0	10.0	10.0	0.0	50.0	30.0	0.0	80.0	0.0
July	97	1	17	17.6	52.9	5.9	0.0	29.4	0.0	0.0	0.0	0.0	11.8	41.2	0.0	0.0
July	99	1	30	30.0	0.0	13.3	0.0	0.0	0.0	0.0	0.0	0.0	43.3	3.3	26.7	0.0
July	97	2	30	50.0	36.7	13.3	0.0	20.0	20.0	0.0	0.00	0.0	6.7	16.7	0.0	0.0
July	99	2	29	13.8	0.0	6.9	0.0	0.0	0.0	0.0	0.0	79.3	3.4	0.0	0.0	0.0
July	97	3	10	0.0	50.0	50.0	10.0	30.0	0.0	0.0	50.0	0.0	10.0	30.0	0.0	0.0
July	99	3	30	0.0	0.0	16.7	0.0	0.0	0.0	0.0	0.0	6.7	93.3	3.3	6.7	0.0
July	97	4	3	0.0	66.6	0.0	33.3	33.3	0.0	0.0	66.6	0.0	66.6	33.3	0.0	0.0
July	99	4	14	14.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	78.6	14.3	7.1	0.0
July	97	5	2	0.0	50.0	50.0	0.0	50.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0.0
July	99	5	3	33.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	33.3	33.3	0.0	0.0
August	97	1	9	0.0	55.6	33.3	0.0	44.4	0.0	0.0	0.0	0.0	33.3	33.3	0.0	0.0
August	99	1	1	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.0	0.0
August	97	2	30	53.3	33.3	3.3	13.2	19.8	0.0	3.3	3.3	0.0	3.3	23.1	0.0	0.0
August	99	2	30	6.7	0.0	50.0	46.7	0.0	0.0	0.0	0.0	6.7	13.4	3.3	10.0	0.0
August	97	3	13	0.0	53.8	7.7	23.1	53.8	0.0	38.5	46.2	0.0	30.8	30.8	0.0	0.0
August	99	3	27	11.1	0.0	40.7	85.2	0.0	0.0	0.0	0.0	0.0	11.1	0.0	7.4	0.0
August	97	4	4	0.0	75.0	0.0	50.0	50.0	0.0	0.0	50.0	0.0	50.0	0.0	0.0	0.0
August	99	4	30	6.7	0.0	40.0	73.3	0.0	3.3	3.3	0.0	6.7	30.0	0.0	10.0	0.0
August	99	5	4	0.0	0.0	50.0	100.0	0.0	0.0	0.0	0.0	50.0	50.0	0.0	0.0	0.0
Sept	97	1	30	16.7	50.0	30.0	0.0	46.7	0.0	0.0	0.0	0.0	20.0	30.0	0.0	0.0
Sept	99	1	13	30.8	0.0	15.4	0.0	0.0	53.8	0.0	0.0	0.0	7.7	0.0	15.4	0.0
Sept	97	2	30	6.7	56.7	33.3	53.3	53.3	6.7	29.7	6.7	3.3	19.8	26.4	0.0	0.0
Sept	99	2	30	46.7	0.0	16.7	0.0	0.0	43.3	0.0	0.0	0.0	0.0	0.0	23.3	3.3
Sept	97	3	20	0.0	70.0	25.0	35.0	50.0	10.0	20.0	25.0	5.0	20.0	40.0	0.0	0.0
Sept	99	3	28	60.7	0.0	7.1	0.0	0.0	17.9	0.0	0.0	0.0	10.7	0.0	0.0	3.6
Sept	97	4	13	0.0	46.1	53.8	15.4	30.8	0.0	0.0	46.1	0.0	46.1	23.1	0.0	0.0
Sept	99	4	23	34.8	0.0	17.4	0.0	4.3	39.1	0.0	0.0	0.0	0.0	0.0	17.4	13.0
Sept	97	5	12	0.0	33.3	41.7	50.0	25.0	8.3	0.0	41.7	8.3	25.0	16.7	0.0	0.0
Sept	99	5	10	70.0	0.0	10.0	0.0	0.0	10.0	0.0	0.0	0.0	0.0	0.0	0.0	20.0

Montana, was 113 and 123 mm, respectively. Although there is some disagreement about length at maturity, our results suggest that some males are reproductively active at age 1 and are all mature by age 2, whereas only a very few females are mature at age 1 and not until age 3 have all females entered the breeding population. Scarnecchia et al. (2000) also noted mature males at age 1 and a few mature females at age 2 in the Yellowstone River, Montana. Our observations are similar to Bishop (1975) and Martyn and Schmulbach (1978), who suggested that sexual maturity was attained by age 2 and 105-mm standard length for the species as a whole.

Food Habits

In 1997, the most frequently consumed prey across all length groups of Flathead Chubs during the April and July samples were Ostracoda, Copepoda, Hemiptera (dominated by Corixidae), and Diptera. During the late summer and into autumn, Ostracoda, Hemiptera, and Copepoda continued to demonstrate frequent presence in the stomach contents; however, Ephemeroptera and Trichoptera became more prevalent in the diets (Table 4). The 1999 frequency of occurrence data indicated that fewer Flathead Chubs were consuming Copepoda and Hemiptera. In addition, Ostracoda were nearly absent from the diets. Alternatively in 1999, Flathead Chub feeding strategies appeared to be more focused on Coleoptera in the spring and early summer and Hymenoptera and

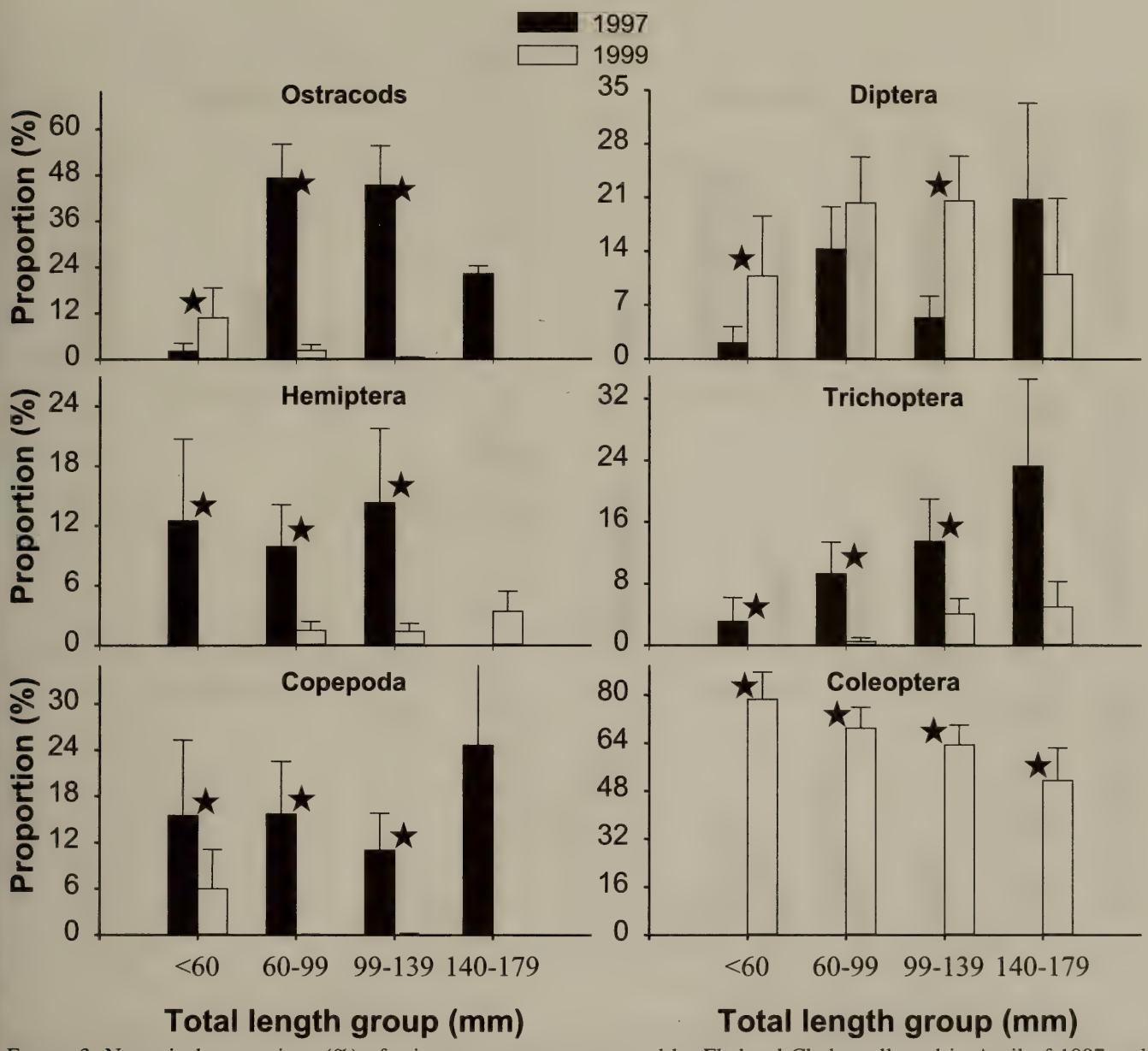

FIGURE 3. Numerical proportions (%) of primary prey taxa consumed by Flathead Chubs collected in April of 1997 and 1999 from the Missouri River, North Dakota. For each pair of bars (1997 and 1999), a statistical comparison was conducted. Those pairs with a ★ designation were significantly different ($P < 0.05$).

macrophytic plant seeds in the late summer and autumn (Table 4).

Numerically, Ostracoda dominated the Flathead Chub diets in 1997, with Copepoda, Hemiptera, Trichoptera, and Diptera also contributing (Figures 3–6). In 1999, Ostracoda, Hemiptera, and Copepoda were significantly less abundant in the Flathead Chub diets ($P < 0.05$) during numerous sample periods and among most length groups (Figures 3–6). The significant decline in several prey taxa was offset by significant increases in the numeric proportions of Coleoptera, Diptera, Trichoptera, Ephemeroptera, and Hymenoptera during several seasons and for various length groups (all tests were $P < 0.05$; Figures 3–6).

The food habits assessment provided evidence that the diets of Flathead Chubs in the high water year of 1997 were substantially different than those observed in the typical water year of 1999. Olund and Cross (1961) noted that Flathead Chubs collected in Alberta rivers had diets similar to those reported here, primarily consuming Corixidae, Hymenoptera, Diptera, and Coleoptera. In addition, Brown (1971) suggested that terrestrial insects were an important food resource during portions of the year.

Cellot and Bournard (1987) noted that backwaters produce a number of invertebrates relatively uncommon in channel habitats. Some of those backwater taxa were the primary contents noted in our Flathead Chub diet analysis in 1997, such as Copepoda zooplankton and Hemiptera. Although Ostracoda can be abundant in the backwater habitats, their origin is not clear. Pennak (1989) noted that seed shrimps (Ostracoda) are well-equipped to thrive in lotic and lentic habitats. The Corixidae and Copepoda, howev-

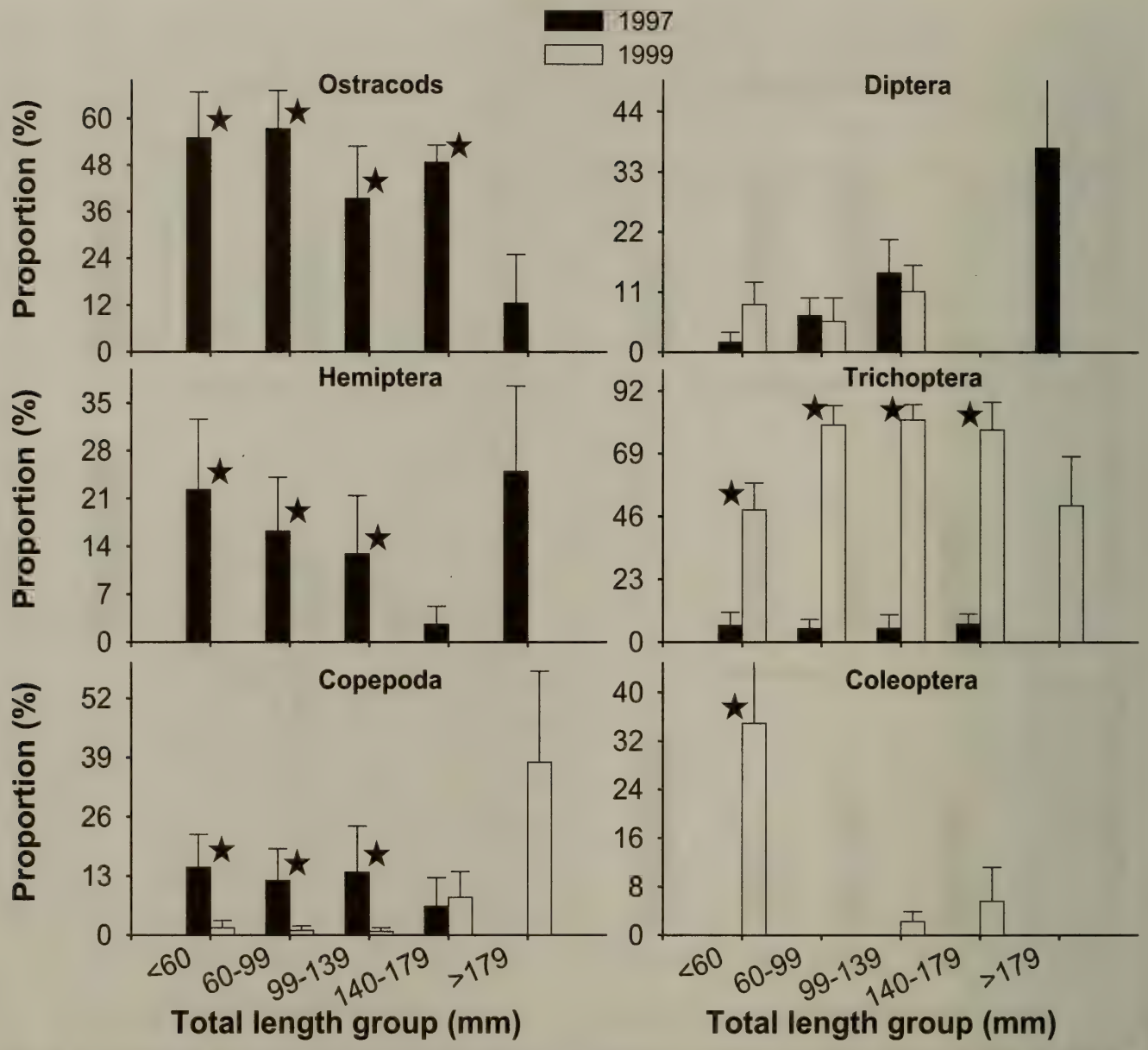

FIGURE 4. Numerical proportions (%) of primary prey taxa consumed by Flathead Chubs collected in July of 1997 and 1999 from the Missouri River, North Dakota. For each pair of bars (1997 and 1999), a statistical comparison was conducted. Those pairs with a ★ designation were significantly different ($P < 0.05$).

er, both tend to be confined to lentic waters and exhibit low densities in lotic habitats (Merrit and Cummins 1984; Pennak 1989). Therefore, the evidence suggests that the high flows in 1997 likely contributed to the altered diets by transporting prey taxa from the floodplain to the channel and/or by washing in-channel food resources away from sandbars at a greater rate than during a typical flow year.

In 1999, the consumption of Coleoptera during April and extending into the other sample months was pronounced. Although reported as Coleoptera, nearly all of the beetles observed in the Flathead Chub stomachs belonged to the family Cicindelidae (tiger beetles). Borror and White (1970) noted that tiger beetles, where present, tended to be very abundant and inhabited open shorelines and beaches. Numerous tiger beetles were observed on the sandbars, and Borror and White (1970) also suggested that the larvae tend to burrow into sandy areas during their juvenile stages. We can only speculate about the mechanisms that made tiger beetles available to Flathead Chubs; however, during the spring and summer of 1999, many tiger beetles were observed in the drift and it is possible that as sandbars shift, late-stage larvae and possibly adults are expunged from their burrows and become more susceptible to fish predation. Alternatively, Flathead Chubs may actively forage into the substrates. Live Flathead Chubs held in the laboratory demonstrated digging behaviors while foraging, at times burying themselves past their pectoral fins. In 1997, the absence of tiger beetles from the diet was conspicuous. It is possible that the inundation of sandbar habitats, which occurred earlier than normal in 1997,

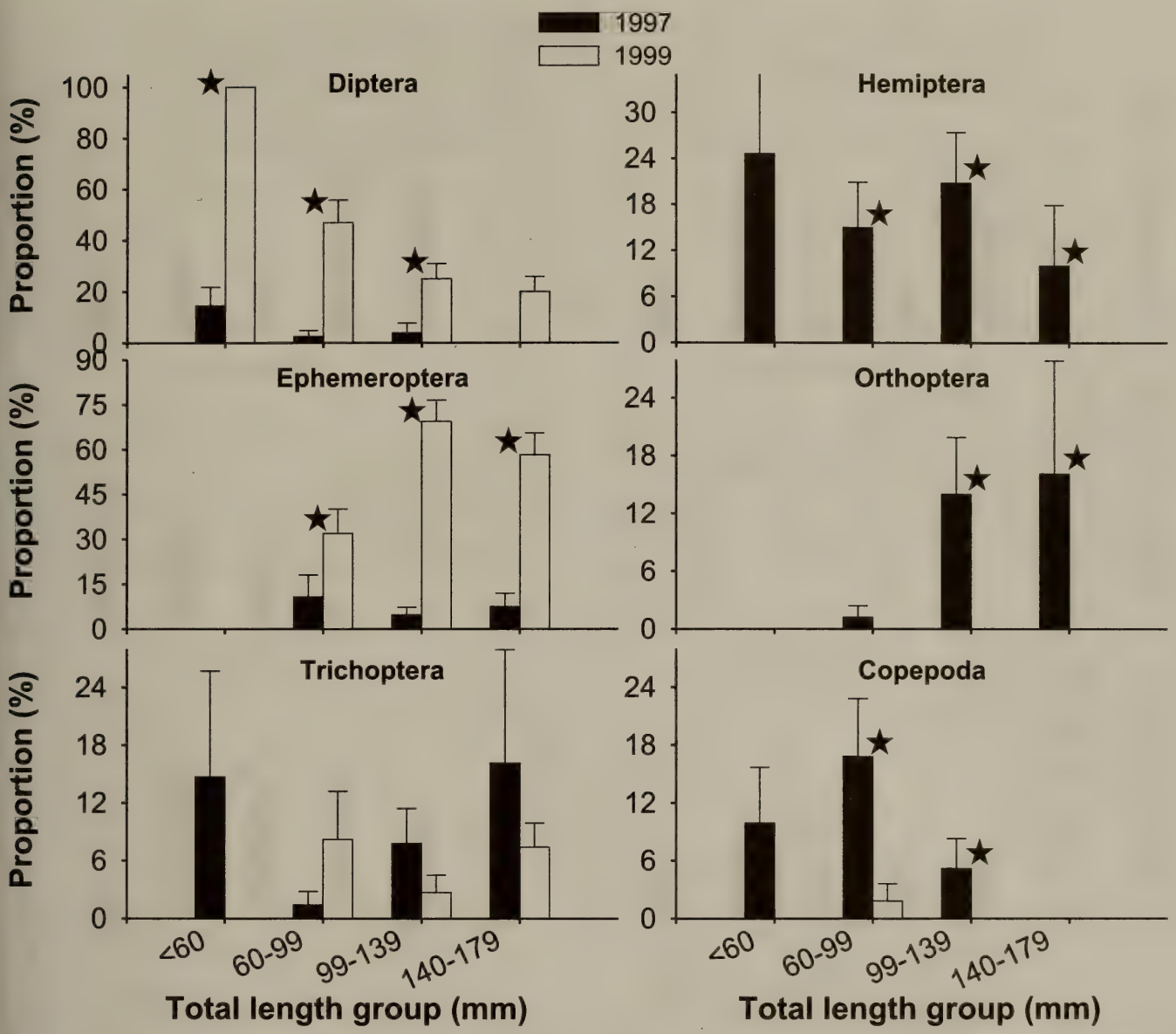

FIGURE 5. Numerical proportions (%) of primary prey taxa consumed by Flathead Chubs collected in August of 1997 and 1999 from the Missouri River, North Dakota. For each pair of bars (1997 and 1999), a statistical comparison was conducted. Those pairs with a ★ designation were significantly different ($P < 0.05$).

removed the staging substrates, either repelling the beetles away from the river bottom in search of better habitats or transporting the organisms out of the feeding area.

The consumption of backwater-originated prey resources by Flathead Chubs during 1999, and more extensively in 1997, suggests that backwater prey production could be important to Flathead Chubs in the Missouri River, particularly during high-flow periods. In a relatively backwater-poor section of the Yellowstone River, Montana, upstream from our study site, Scarnecchia et al. (2000) also collected Flathead Chub in 1997, but found that 98% of the stomachs were empty. The high 1997 flow rates may have transported more typical Flathead Chub prey into unusable areas; therefore, the increased consumption of backwater-oriented food resources may have been a compensatory effort to obtain nutrition. We did not document any empty stomach proportions greater than 70%, and for most Flathead Chub length categories and sample periods, empty stomach proportions were typically < 40% (Table 4). It is unclear if the backwater prey availability was sufficient to provide adequate rations for the Flathead Chub population.

Age and Growth

To complete the back-calculation process, we needed to obtain a Flathead Chub intercept, or a-value, for the scale radius to total body length relationship. A regression analysis based on all fish collected provided an a-value of 32 mm. This value seemed somewhat high considering that many smaller species, such as the darters, *Etheostoma* spp., typically have a-values less than 22 mm (Carlander 1997) and larger species such as Walleye, *Stizostedion vitreum* and White Bass, *Morone chrysops*,

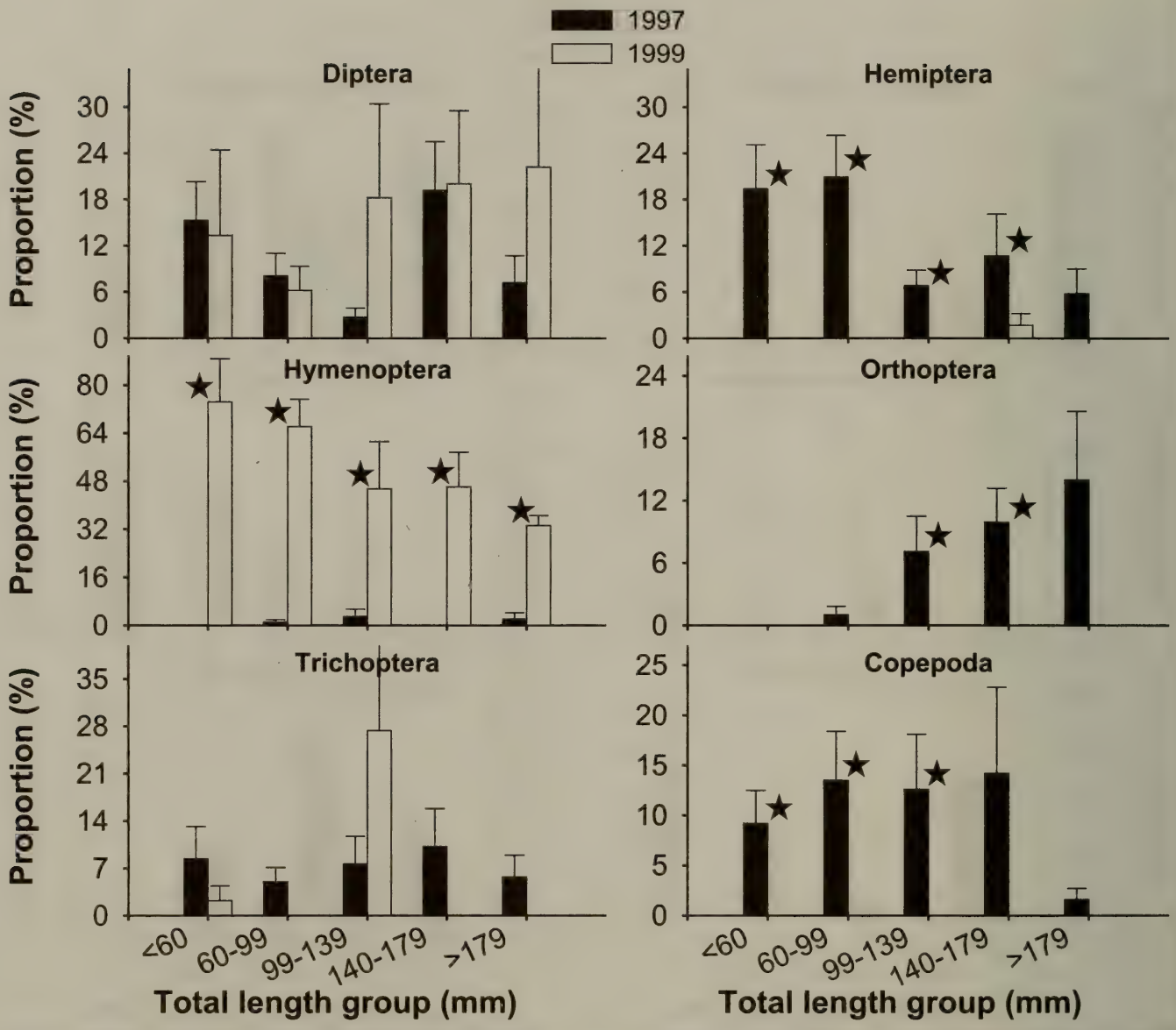

FIGURE 6. Numerical proportions (%) of primary prey taxa consumed by Flathead Chubs collected in September of 1997 and 1999 from the Missouri River, North Dakota. For each pair of bars (1997 and 1999), a statistical comparison was conducted. Those pairs with a ★ designation were significantly different ($P < 0.05$).

have a-values greater than 30 mm (Carlander 1982; Beck et al. 1997). To help validate the use of a 32-mm intercept during the back-calculations, we further assessed the Flathead Chub specimens in our collection that were < 40-mm TL and in good body condition. Upon further inspection, all of the Flathead Chubs < 30-mm TL were scaleless and did not appear to be physically damaged in any way to indicate that scales may have been dislodged during handling. Of the remaining Flathead Chubs < 40-mm TL, 45% of those between 30- and 35-mm TL were scaled and by 38-mm TL, all specimens had scales with discernable circuli. Therefore, the a-value of 32 mm was used with relative confidence.

Aging the Flathead Chub scales was a difficult process and the agreement proportion between the two initial readers (both inexperienced) was 42%. Likewise, Scarnecchia et al. (2000) indicated that Flathead Chub scale aging was challenging. Gould (1985) relied upon length-frequency histograms to identify year classes after unsuccessful attempts to age Flathead Chubs with scales, vertebrae, and opercula. The length-frequency histograms that we formulated for this Missouri River population did not allow us to confidently identify cohorts (Figure 2). Although early age groups can be discerned on the length-frequency histograms, variability was too high to rely on that technique. Therefore, we consulted other cyprinid researchers and aging experts. After receiving a cyprinid aging tutorial, we re-aged the scales with three readers (2 inexperienced and 1 experienced) and reached a consensus age on 96% of the scales. The remaining 4% were eliminated from the analysis due to our inability to assign an age. Our age analysis indicated that the maximum age of Flathead Chub in our collection was 5 years. Therefore, considering growth and maturation patterns, many females may only release eggs in one or two seasons.

TABLE 5. Mean back-calculated total lengths (TL; mm) at age for Flathead Chubs collected in 1997 and 1999 from the Missouri (MO) River in North Dakota. Standard errors are in parentheses. Also noted are total lengths (mm) at age for Flathead Chubs from Perry Creek, Iowa (Martyn and Schmulbach 1978) and from the Peace River, Alberta [Bishop (1975); fork lengths converted to total length using conversion in Martyn and Schmulbach (1978)].

Age	MO River (N)	MO River (TL)	Perry Creek	Peace River
1	85	104.1 (2.8)	77.8 (0.6)	100.4 (NA)
2	37	152.9 (4.7)	109.6 (0.5)	123.6 (NA)
3	17	186.4 (3.8)	130.0 (0.5)	152.2 (NA)
4	6	223.2 (6.9)	148.0 (2.3)	164.9 (NA)
5	1	267.0 (NA)	NA	179.2 (NA)

The back-calculated lengths at the time of annulus formation for each age group suggested that Flathead Chubs, on average, increase their length by approximately 46% between ages 1 and 2, but then growth slows and plateaus at annual length increases of 19–22% during the remainder of their life (Table 5).

Incremental growth analyses for Flathead Chubs collected in September of each year indicated that portions of the Flathead Chub length range, including those between the total lengths of 95 and 135 mm, significantly increased at a more rapid rate during 1997 than did similar sized fish in 1999 ($P < 0.02$;

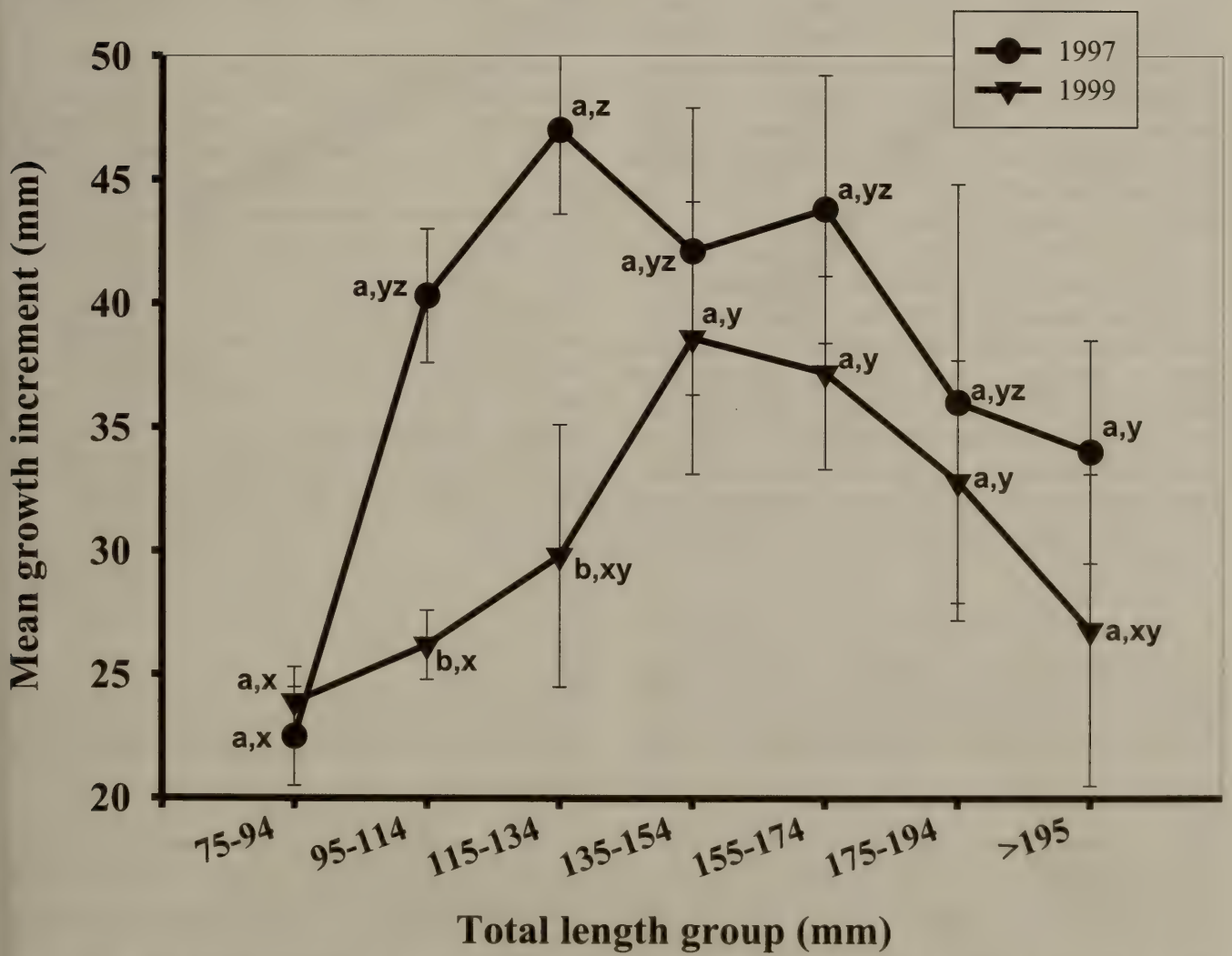

FIGURE 7. Mean growth increments for Flathead Chubs collected in the Missouri River, North Dakota in September of 1997 and 1999. The increments represent estimated growth from the time of annulus formation to the time of capture each year. The letters a and b represent the statistical comparison between years for each total length group noted on the x-axis (vertical comparison). The letters x, y, and z denote the comparison results among total length groups within each sample year (horizontal comparison). Means with the same letters were not statistically different ($P > 0.05$).

Figure 7). With the exception of those age-1 chubs less than 95-mm TL, all length groups had higher mean increments in 1997 than in 1999; however, differences for groups >134-mm TL were not statistically significant ($P < 0.05$). In 1997, the longest growth increments were attained by chubs between 95 and 174 mm, whereas in 1999, chubs between 95 and 135 mm had significantly lower growth increments ($P < 0.05$; Figure 7).

As compared with the maximum age of 5 reported here, Martyn and Schmulbach (1978) found Flathead Chubs up to age 4 in Perry Creek, Iowa; however, Scarnecchia et al. (2000) suggested that Flathead Chubs in the Yellowstone River, Montana, reached age 7 and Bishop (1975) noted that the maximum life span of Flathead Chubs in the Peace River, Canada was 10 years. Additionally, the longest Flathead Chub in our sample was 275-mm TL, whereas Kristensen (1980) reported capturing 293 Flathead Chubs in the Peace-Athabasca River delta in Canada that had a mean TL of 345 mm. The substantially higher total length and longevity reported for Flathead Chubs in the northern portions of the species range may be attributed to less disruption of recruitment patterns and cooler water temperatures that moderate metabolic activity, ultimately extending the average potential life span. The population of Flathead Chub utilizing the sandbar habitats in this study was dominated by individuals ≤ age 3.

Brown (1971) reported lengths at ages 1–3 for Flathead Chubs in Montana; however, no indication was given pertaining to how these lengths and ages were derived or if the measurements were in total, fork, or standard length (Table 5). Martyn and Schmulbach (1978) aged Flathead Chub scales collected from specimens in Perry Creek, a Missouri River tributary in Iowa, and noted lengths considerably shorter for each age group than those reported in our study (Table 5). Gould (1985) also noted three Flathead Chub total length modes at 43-, 81-, and 116-mm TL in the March length-frequency histogram from the Musselshell River, Montana, but did not suggest that the modes represented age groups. Our assigned ages and back-calculated lengths at age differed from several other reports, but were similar to those reported at ages 1–5 in the Peace River, Alberta (Bishop 1975). We believe that our aging was done appropriately and given the wide variability of habitats and phenotypical expression across the species range, our results should be representative of the Flathead Chub population found in the study area.

Although understanding mean growth patterns for Flathead Chubs as a population is valuable, we were particularly interested in the growth rates during 1997 and 1999 when the diets significantly differed. The cohorts of Flathead Chubs in 1997 utilized prey that were likely backwater originated, including Copepoda and Hemiptera, at a significantly higher rate than the same cohorts did in 1999 (Figures 3–6). Food resources that appeared to have backwater origination were nearly absent from the chub diets in 1999. This dietary absence may have influenced the growth rates of different length groups to varying degrees, especially when considering feeding efficiency and food item assimilation patterns that can cause substantial changes in the bioenergetics of different cohorts within a species (Adams and Breck 1990).

In addition to changes in diet, environmental conditions can also alter bioenergetic functions and affect fish growth rates and body condition by directly influencing metabolism and prey dynamics (e.g., Kitchell et al. 1977; Swenson 1977). In 1997, water temperatures were cooler in the early portions of the annual flood pulse (i.e., April and May), but were significantly warmer ($P < 0.05$) from July through September (Table 2). The higher summer and fall temperatures in 1997 may be attributable to the extended exchange of water between the floodplain and the channel. Waters retained in backwaters and other floodplain wetlands tend to be substantially warmer, as was demonstrated in 1999 when the backwaters functioned in an uncoupled manner from the channel (Table 2). The higher temperatures in 1997 may have contributed to the increases in growth increments that could also be noted on the scales from fish collected in 1999, particularly those that were ages 1 and 2 in 1997.

Body Condition

Regardless of sample period, Flathead Chubs captured in the mean flow year of 1999 weighed less at

TABLE 6. Weight-length equations for Flathead Chubs captured in various sample periods in 1997 and 1999 from the Missouri River in North Dakota. Statistical comparisons (analyses of covariance), represented by their p-values, between years for intercepts (a) and slopes (b) are noted. Weight (wt) is in grams and total length (TL) is in mm.

	Weight-length equations		P-values	
Period	1997	1999	a	b
April	$\log_{10}wt = -5.369+3.065(\log_{10}TL)$	$\log_{10}wt = -4.680+2.802(\log_{10}TL)$	0.001	0.001
July	$\log_{10}wt = -5.621+3.226(\log_{10}TL)$	$\log_{10}wt = -5.028+2.997(\log_{10}TL)$	0.001	0.001
August	$\log_{10}wt = -4.902+2.853(\log_{10}TL)$	$\log_{10}wt = -5.245+3.107(\log_{10}TL)$	0.006	0.001
September	$\log_{10}wt = -5.349+3.063(\log_{10}TL)$	$\log_{10}wt = -4.918+2.938(\log_{10}TL)$	0.001	0.001

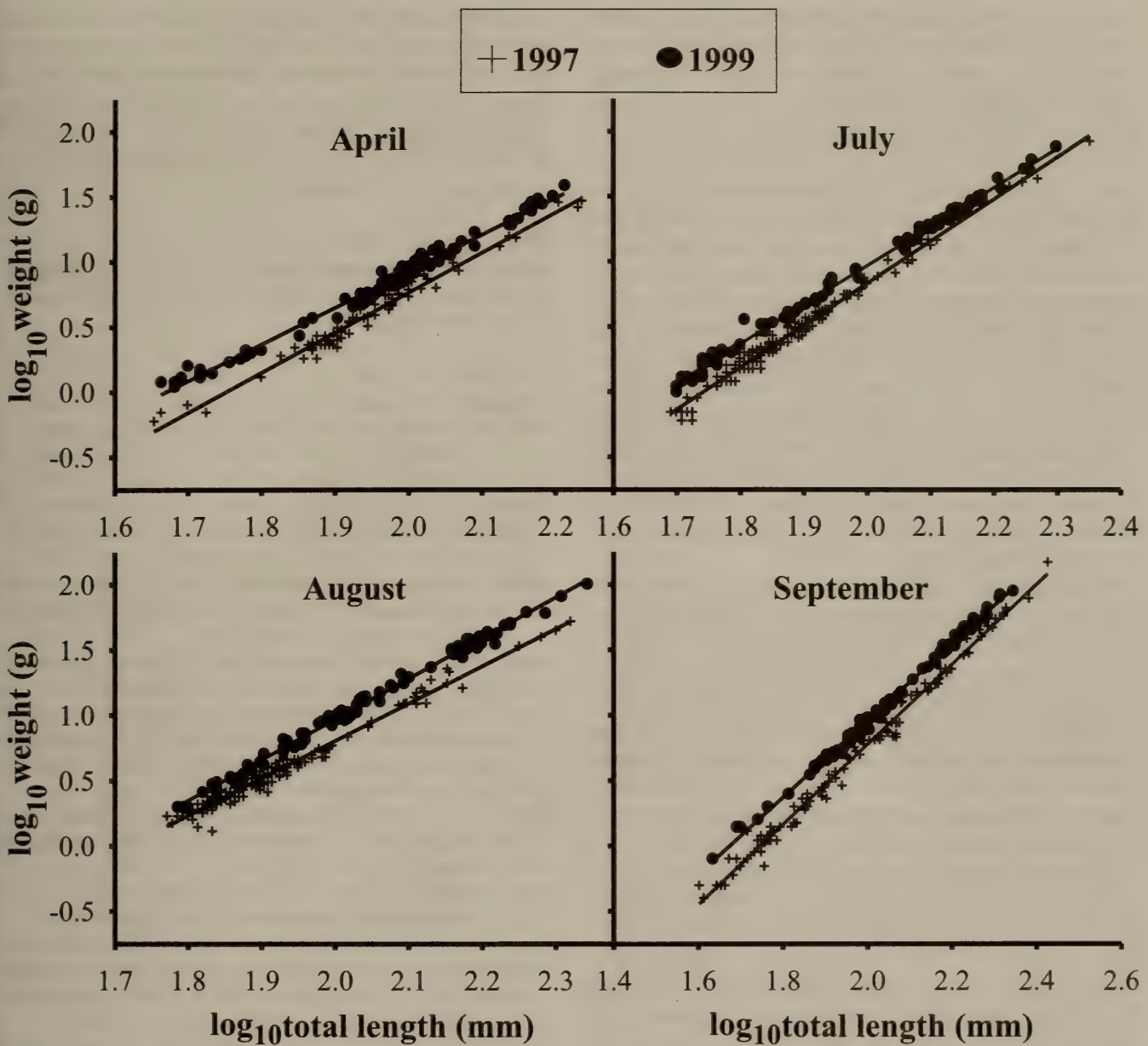

FIGURE 8. Weight-length relationships (log10 transformed) from Flathead Chubs collected in the Missouri River, North Dakota, during various periods of 1997 and 1999. The cross-hair markers denote chubs collected in 1997 and the circles represent those collected in 1999. The regression relationship for each set of data is depicted with a solid line. Statistical analyses for these data are summarized in Table 6.

all comparable lengths than in 1997 (Figure 8). The intercept values and slopes of these regression analyses were all significantly different between years during each sample period ($P < 0.006$; Table 6). During some sample periods, the 1999 predicted weights for some Flathead Chub lengths exceeded the 1997 predicted weights by as much as 50%.

The weight-length equations reported here were similar to those documented by Gould (1985); however, that study did not identify any significant differences in slopes or intercepts among sample periods. It would be reasonable to hypothesize that when the environment favors increased growth rates (based on total length), that the habitats would also be favorable for individuals to maintain high body condition (plumpness). Although the logic of this argument seems apparent, our data suggest that Flathead Chubs in 1997 acquired greater total length additions, but did so while they were less plump. Fish condition has been correlated with prey availability in many lentic populations (Wege and Anderson 1978; Liao et al. 1995; Marwitz and Hubert 1997; and Porath and Peters 1997), but we are aware of no such analyses for lotic fish populations.

We cannot explain the contradictory condition and growth observations discussed above; however, it could be hypothesized that during a year when flow velocity is high (e.g., 1997) it is ecologically advantageous for a fish to be more fusiform than when under conditions of lower flow rates. Fisher et al. (1996) noted that healthy burbot, *Lota lota*, popula-

tions from lotic systems consistently maintained lower overall body condition; however, annual variation in these condition measures was not assessed. Although Flathead Chubs in 1997 were thinner and had to cope with higher turbidity levels (Table 2), the population was also provided with food resources and warmer water temperatures due to the higher rate of floodplain interaction. Scott and Crossman (1973) noted considerable morphological variation in Flathead Chubs across its North American range and Olund and Cross (1961) suggested that subspecies, based on morphological features that included differences in total length to circumference ratios, be recognized. However, Bailey and Allum (1962) hypothesized that the manifestations were strictly related to environmental conditions, not genetic strains. The substantial differences that we observed between two years within the same Flathead Chub population support the plasticity suggestion of Bailey and Allum (1962).

Flathead Chub food habits are often referred to in general, but seldom supported with documentation (e.g., McLane 1978; Baxter and Stone 1995). Brown (1971) reported that biologists in Montana believe the Flathead Chubs feed on aquatic invertebrates, extensively utilize abundant terrestrial insects that become part of the drift, and are sufficiently omnivorous to feed on vegetative matter. Our results support these assumptions, including the sporadic feeding on plant tissues. Our data indicate that diets vary substantially during differential hydrograph cycles and, when combined with varied flows and other environmental conditions, influence growth rates and condition. The backwater-produced prey appeared to be utilized by small to mid-sized Flathead Chubs. We were unable to determine if Flathead Chubs prefer the backwater organisms or are using their availability to compensate for absent channel resources during high flow periods. Riverine ecologists (e.g., Kennedy 1979; Eckblad et al. 1984) have assumed that backwater habitats are critical to native fishes evolved in large river systems. We documented limited direct physical use of backwater habitats by Flathead Chubs during any life history stage; however, the indirect benefits of floodplain prey production and water conditioning are possibly critical during high flow hydrographs.

Acknowledgments

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Abundance and Distribution of Breeding Waterfowl in the Great Clay Belt of Northern Ontario

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The abundance and distribution of breeding waterfowl in the Great Clay Belt of northern Ontario was determined through helicopter surveys of 117 fixed plots (2 × 2 km each) during the nest initiation periods from 1988 to 1990. This area has higher fertility, flat topography, high water table and better access than the surrounding Boreal Forest, and therefore has greater potential for increased waterfowl production through habitat management. Overall breeding density averaged 112.5 indicated breeding pairs per 100 km^2, 68% being of the four most common species [Mallard (*Anas platyrhynchos*), Ring-necked Duck (*Aythya collaris*), American Black Duck (*Anas rubripes*), and Common Goldeneye (*Bucephala clangula*)]; 13 other species were encountered. The average total of breeding waterfowl for the region was estimated at 59330 pairs. Distributions of the species were related to ecodistrict and to surficial geology. The more northerly of the two main ecodistricts had higher densities of American Black Ducks, Ring-necked Ducks, Common Goldeneyes, and Canada Geese (*Branta canadensis*). Mallard and Hooded Merganser (*Lophodytes cucullatus*) distributions correlated with presence of surficial clay and moraines, respectively. Less common species including Green-winged Teal (*Anas crecca*) and American Wigeon (*Anas americana*) appeared to be concentrated in smaller-scaled habitat features (beaver pond sequences and estuarine marshes, respectively). Results generally agreed with those of earlier Clay Belt surveys. Total breeding density of waterfowl is slightly higher than that of surrounding regions.

Key Words: ducks, populations, habitat, boreal, forest, Ontario

The boreal forest region in eastern Canada has been largely ignored as an important area for waterfowl production owing to its relatively low fertility and often difficult accessibility when compared to the prairies. An initial assessment by Hanson et al. (1949) based on the limited information available at the time concluded that the area was of minimal importance to most waterfowl populations. However, as more quantitative surveys were applied, initially by the U.S. Fish and Wildlife Service in the 1950s and 1960s (Addy et al. 1952, Kaczynski and Chamberlain 1968), it became clear that, while breeding densities were low, the vast area of the boreal forest made its contribution to continental waterfowl stocks substantial (Wellein and Lumsden 1964). The accuracy of these earlier surveys was limited by the difficulty of observing waterfowl in forested wetlands from fixed-wing aircraft (Chamberlain and Kaczynski 1965). In Ontario, it was only when more intensive and efficient survey methods were applied that breeding density estimates for the full range of waterfowl species could be made (Dennis 1974; Ross 1987). These intensive surveys revealed that different physiographic units of the boreal forest had characteristic waterfowl species compositions. One such unit is the Great Clay Belt, also known as the Northern Clay Section (B4 *in* Rowe 1972), and hereafter termed the Clay Belt in this paper. In Ontario, the Clay Belt extends east from Hearst to the Quebec border and south approximately to Timmins (see Figure 1); the remainder of this unit occupies an area of roughly similar size in contiguous Quebec. The Clay Belt is unique in having a rich clay soil in contrast to low fertility habitats of muskeg and exposed-bedrock shield surrounding it. The higher fertility of the Clay Belt is evidenced by higher rates of wetland occupancy by waterfowl than in adjoining areas (Dennis 1974). Moreover, the combination of its general fertility and flat topography, high water table, and relative accessibility due

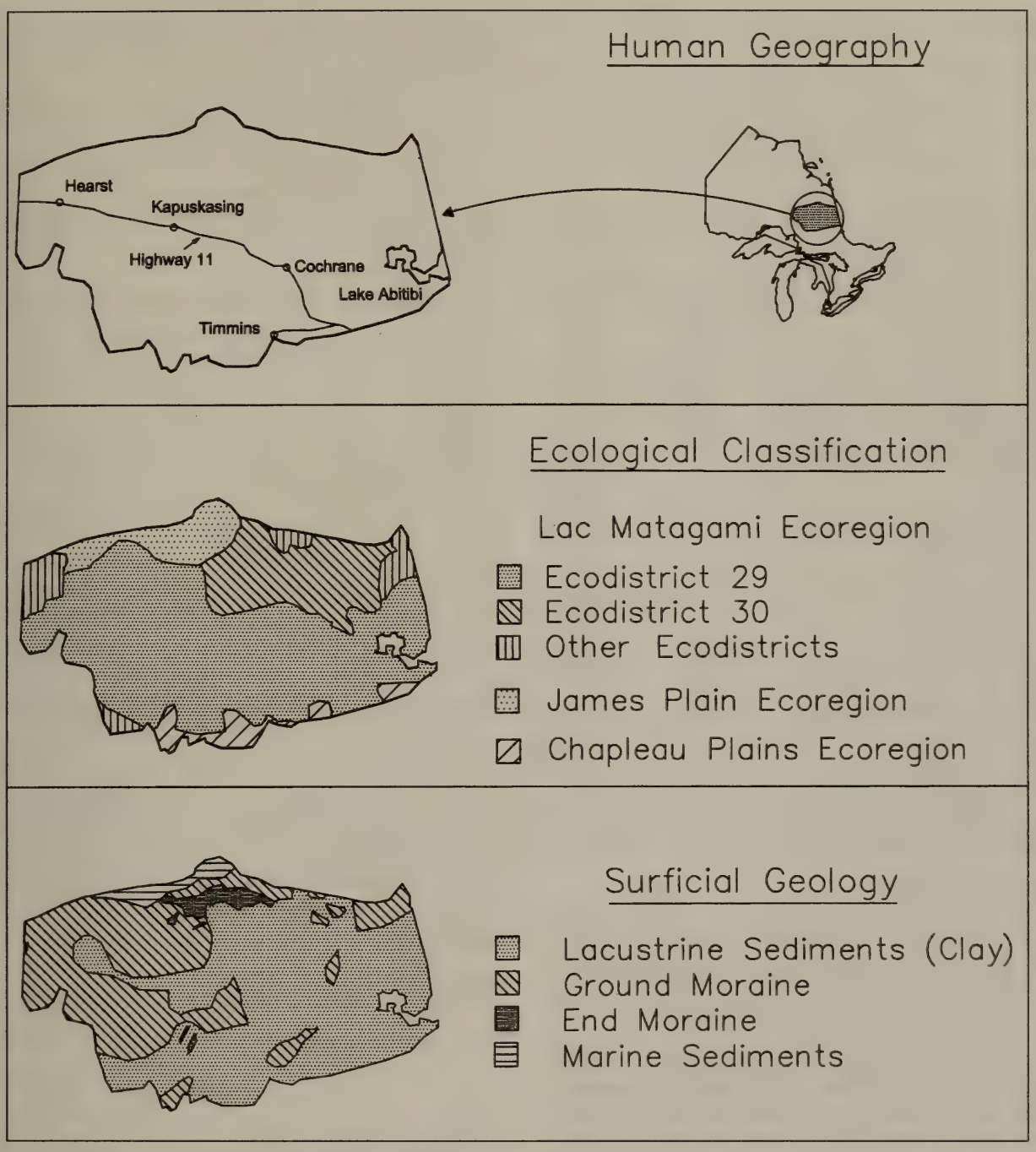

FIGURE 1. Geographical locations, ecological classification, and surficial geology units of the Great Clay Belt of Ontario.

to the extensive network of roads for logging and mining, gives the Clay Belt greater potential for enhanced waterfowl production through habitat management than in the neighbouring boreal forest. This importance is well-recognized and the Clay Belt is included as a priority area in the Eastern Habitat Joint Venture of the North American Waterfowl Management Plan (NAWMP Update 1994).

Maximizing the effectiveness of management activities requires knowledge of the breeding distributions and habitat preferences of various waterfowl species frequenting the area. A study of waterfowl productivity across the Clay Belt of Ontario was therefore undertaken jointly by Ducks Unlimited Canada, the Ontario Ministry of Natural Resources and the Canadian Wildlife Service. The main objectives were to: (1) assess species composition, density, and distribution of the waterfowl community, (2) determine habitat correlates of nesting and brood-rearing waterfowl, and (3) develop a wildlife habitat map using LANDSAT. This paper describes waterfowl species composition, density and distribution across the Clay Belt, relates these to broad habitat patterns in the area, and estimates the contribution of the Clay Belt to overall waterfowl populations in northern Ontario.

Methods

Study Area

The Clay Belt is a relatively flat, humid forest region corresponding to an area occupied by former glacial lakes Ojibway and Barlow (Rowe 1972; Sharpe and Brodie 1931). Bedrock is mostly overlain by sedimentary clays and extensive peatland. There are relatively few large lakes, and streams and rivers are generally low gradient compared to adjacent exposed Precambrian shield areas. Tree species of the Clay Belt reflect this topography and geological history. The main tree species is Black Spruce (*Picea mariana*) which occurs on flat lowlands and moister uplands. In areas of better local drainage, species include White Spruce (*P. glauca*), Trembling Aspen and Balsam Poplar (*Populus tremuloides, P. balsamifera*), White Birch (*Betula papyrifera*), and Balsam Fir (*Abies balsamea*). Jack Pine (*Pinus banksiana*) occurs widely on sandy, drier sites such as eskers, moraines and outwash plains. Clay areas were cleared for agriculture in the 1930s and 1940s; these are limited in extent and distribution around communities on or very near Highway 11, which bisects the study area from southeast to northwest (Figure 1). Wetlands vary widely in size, and beaver impoundments on the many low gradient streams account for many of them. A wetland classification system for the area and an assessment of its relevance to duck species in the Clay Belt was developed by Rempel et al. (1997) as part of this study.

Population Estimation

Distribution and abundance of breeding waterfowl in the Clay Belt was determined by aerial surveys of fixed plots during nest initiation periods in 1988, 1989 and 1990. These plots were selected using a two-staged process in which the whole Clay Belt was divided into a grid of 10×10 km blocks following the UTM system. Each block was then subdivided into $25 - 2 \times 2$ km plots, and one plot selected at random from each block for a total of 117 plots. This sampling regime allowed us to describe species distribution, and to statistically estimate population size and habitat correlations.

Surveys were carried out by helicopter (after Ross 1985, 1987). All surveys were done from a Bell 206B helicopter on high skids and equipped with a range extender on the fuel tank and bubble observation windows on the back doors for improved visibility. Two observers in the back watched for waterfowl from their respective sides of the aircraft, and passed observations by intercom to the navigator/recorder in front. That person wrote these directly onto acetate-covered aerial photographs, recording species, sex, numbers, and exact locations of all waterfowl; care was taken to ensure that sightings came from within the boundaries of the plots. The aircraft passed over all suitable habitat in each plot at altitudes as low as 20 m, and at speeds ranging from a hover to 100 km/h. Multiple passes were made over those waterbodies where the initial coverage was thought to be inadequate or where birds seen were not initially identified. Because most wetlands in the Clay Belt are small and clearly bounded, total coverage of all wetlands in the plots was accomplished by following shorelines, and no transects were employed. All plots were surveyed during the following periods: 10–21 May 1988, 20–26 May 1989, and 20–22 May 1990.

Results of the survey are expressed as numbers of indicated breeding pairs (IBP) per species. For clearly dimorphic species, IBP was based on the total of lone males, pairs, and number of males in flocks with up to 5 males (as in Dzubin 1969). For American Black Ducks (*Anas rubripes*) which are more weakly dimorphic, determination of sex was successful in about 90% of the cases; the remaining Black Ducks were ascribed indicated pair values based on the average proportions of indicated pairs to number of individuals in the three sighting classes (lone birds, two-bird groups, flock of three or more) as taken from all breeding pair surveys in northeastern Ontario from 1988 to 1990 (Ross, unpublished data). Indicated pairs for Canada Geese (*Branta canadensis*) were counted for each single, pair, or group of three. Counts of indicated pairs on the plots based on this helicopter survey technique are comparable to intensive ground survey results and are considered sufficiently close to the real values to be used directly in breeding density calculations (Ross 1985); no visibility correction factors have been applied.

Habitat Parameters

Although the Clay Belt is designated as a single forest section by Rowe (1972), other classifications can be used to subdivide this area to examine broad patterns in waterfowl distribution. In Figure 1, we present two classifications of the region. The first is an ecological classification showing the boundaries of the ecoregions and ecodistricts (Wicken 1986; Wickware and Rubec 1989); an ecodistrict is defined as a part of an eco-region characterized by a distinctive pattern of relief, geology, geomorphology, vegetation, soils, water, and fauna. A second classification portrays substrate and is based on the surficial geology of the region (Glacial Map of Canada, Geological Survey of Canada). To aid in interpretation of waterfowl distribution data, amounts of various potential nesting habitats (wetland associated with standing water) in each plot were measured by electronic planimeter, and number of water bodies were counted.

Statistical Analysis

Overall breeding densities in both ecodistrict and substrate units were compared using a Mann-Whitney U Test (from Siegel 1956). Contour maps

TABLE 1. Breeding densities of waterfowl of the Clay Belt (present and earlier studies) plus estimates of population sizes from present study.

Source	Dennis (1974)	Ross (1987)	Present Study				
Year	1973	1982	1988	1989	1990	Mean (1988–1990)	
Parameters	Breeding Density (IBP/100 km²)						Population Size (range)
Species							
Canada Goose	–	1.0	1.98	3.24	2.36	2.52	1330 (1040–1710)
Wood Duck	–	1.0	0.54	2.88	2.17	1.86	980 (290–1520)
Green-winged Teal	9.7	4.0	4.50	8.27	11.96	8.21	4330 (2370–6310)
American Black Duck	31.3	10.2	16.09	19.85	20.09	18.72	9870 (8490–10600)
Mallard	23.2	21.0	21.22	29.50	24.09	24.88	13120 (11190–15560)
Blue-winged Teal	6.2	6.0	3.96	7.01	6.70	5.88	3100 (2090–3700)
American Wigeon	17.8	–	2.16	2.88	3.99	3.00	1580 (1140–2100)
Other Dabblers	–	–	–	0.54	0.18	0.24	130 (0–290)
Ring-necked Duck	12.4	18.0	16.01	22.66	24.09	20.90	11020 (8440–12710)
Lesser Scaup	–	–	0.72	0.72	2.90	1.44	760 (380–1530)
Common Goldeneye	27.8	11.0	11.51	11.70	13.22	12.11	6390 (6070–6970)
Bufflehead	–	–	0.90	0.90	0.72	0.84	440 (380–470)
Hooded Merganser	3.1	4.0	6.65	5.40	8.15	6.71	3540 (2850–4300)
Common Merganser	–	6.0	5.58	3.78	5.25	4.95	2610 (1990–2940)
Other Divers	1.3	–	–	0.54	0.18	0.24	130 (0–290)
Total	132.8	82.2	91.81	119.85	126.07	112.50	59330 (48420–66490)

of breeding pair densities and other parameters were generated using surfaces created by the potential mapping routine (POTMAP) of the SPANS geographical information system (INTERA TYDAC Inc. 1991) and are based on sequential averaging of point values encompassed within an outer circle of 47 km of the each specific plot value; an inner circle of 10 km holds the specific plot value constant over that area.

Results and Discussion

Waterfowl Population Sizes

Breeding densities of the more common waterfowl species for each of the three years are presented in Table 1. Densities, for each species, were similar in 1989 and 1990, but those for 1988 were consistently lower for dabbling ducks and Ring-necked Ducks (*Aythya collaris*). These differences reflected outlier values generated when very low counts were made in 1988 on a small number of plots that had much higher numbers in later years. Because annual variation in waterfowl numbers in boreal systems is not well known and the ranges of values were less than 20 percent of the average for the most common species, we used three-year means to represent average breeding densities of waterfowl species in the Clay Belt (Table 1).

Overall breeding density of waterfowl was 112.5 IBP/100 km²; the four most common species (68% of total IBP) were American Black Duck, Mallard (*Anas platyrhynchos*), Ring-necked Duck, and Common Goldeneye (*Bucephala clangula*). Less common, but widely encountered (4 species, 23% of total IBP), were Green-winged Teal (*Anas crecca*), Blue-winged Teal (*Anas discors*), Hooded Merganser (*Lophodytes cucullatus*), and Common Merganser (*Mergus merganser*). The remaining nine percent included five uncommon and locally occurring species [Canada Goose, Wood Duck (*Aix sponsa*), American Wigeon (*Anas americana*), Lesser Scaup (*Aythya affinis*), Bufflehead (*Bucephala albeola*)], plus four rare species [Northern Pintail (*Anas acuta*), Northern Shoveler (*Anas clypeata*), Surf Scoter (*Melanitta perspicillata*), and White-winged Scoter (*Melanitta fusca*)]. Estimates of breeding populations of all but the rare species (also in Table 1) were generated by multiplying average densities by the area of the Ontario Clay Belt (52 740 km²), to give an average total of 59 330 breeding pairs of waterfowl in this area (range: 48 420-66 490).

Habitat Characteristics

Only the two largest ecodistricts (Numbers 29 and 30) had sufficient numbers of survey plots (81 and 20, respectively; 86% of all plots) for separate analysis. Ecodistrict 30 had a lower elevation and a greater proportion of standing water than did Ecodistrict 29 (Wickware and Rubec 1989). Amount of waterfowl breeding habitat and number of water bodies per plot were significantly higher in Ecodistrict 30 (Table 2). Ecodistrict 29 contained most of the agricultural areas and much of the area that has been logged (Hutton and Black 1975).

Surficial geology is another way of subdividing the Clay Belt (Figure 1). Although lacustrine sediments, essentially clay, are the dominant substrate, much of the study area, particularly toward the west, is underlain by ground moraines with several smaller sections of end moraines. As clay usually contributes to greater ecological productivity, we expected that its presence should influence the distribution of some species. No statistical difference was found in number of water bodies or the total area of wetlands in plots of the two substrates (Table 2).

Waterfowl Distribution

Distributions of individual species are displayed as contoured maps based on mean breeding density per plot (Figure 2) for all species that were recorded on more than nine different plots. In Table 3, breeding densities of these species are compared between the two ecodistricts and between the two substrate types.

The most abundant species was the Mallard that was found throughout the area with highest densities following a diagonal band (northwest-southeast) across the Clay Belt. There was no difference in breeding density between ecodistricts, but density was higher on plots with a clay substrate. Although habitat fertility influences Mallard distribution (Merendino and Ankney 1994), the area of highest breeding density is also that with most agricultural and tree-harvesting activities, which produce prairie- and parkland-like habitats to which Mallards are well-adapted (Bellrose 1980).

American Black Ducks were abundant and widespread in the Clay Belt (second amongst dabbling ducks, third overall). Highest breeding densities occurred in the north. Of the two ecodistricts, significantly higher breeding density was encountered in Ecodistrict 30, but unlike Mallards, no relationship was found between breeding density and substrate. Although Mallards and Black Duck are closely related and interbreed, their distributions did not show the same patterns even though they were among the most common species (see also Ross and Fillman 1990).

The most common diving ducks in the Clay Belt (and second most abundant duck overall) were Ring-necked Ducks. Their density distribution was similar to that of Black Ducks, with which they regularly co-occur (McNicol et al. 1987). Ecodistrict 30 supported higher breeding densities, but there was no relationship with substrate.

Common Goldeneye was the fourth most abundant species, and like Black Ducks and Ring-necked Ducks, they occurred in significantly higher density in Ecodistrict 30 than in Ecodistrict 29, and there was no correlation between distribution and substrate.

Green-winged Teal were observed throughout the study area but did not show a pattern explainable by either ecodistrict or substrate classifications, suggesting that the birds were using specific habitat types with distributions unrelated to these factors. In the Clay Belt, occurrence of this species is significantly associated with Beaver pond systems (Rempel et al. 1997). Paquette and Ankney (1996) demonstrated high specificity in wetland use by this species in British Columbia.

Hooded Mergansers occurred in moderate numbers. High density zones largely coincided with those of Common Goldeneye, which may reflect the distribution of suitable nesting cavities for which the two species have similar requirements (Lumsden et al. 1980). No relationship with ecodistrict was evident, but breeding density was significantly higher in areas with moraine substrate than in those underlain by clay; the latter substrate may produce greater turbidity in waterbodies making them less suitable for foraging by this species (Bellrose 1980).

Blue-winged Teal distribution showed the same diagonal band component as that of Mallard with which it shares the ability to exploit more open habitats (Bellrose 1980). Numbers were too low, however, to determine any relationship with either ecodistrict or substrate type.

Common Mergansers showed concentrations in those parts of the northern part of the Clay Belt that

TABLE 2. Comparison of summary measures of waterfowl community parameters and habitat by ecodistrict and substrate.

Classification	Ecodistrict			Substrate		
(a) Waterfowl Community Parameters	29 (n = 81)	30 (n = 20)	Significance (p)	Clay (n = 72)	Moraine (n = 43)	Significance (p)
Total Breeding Density (IP/100 km^2)	95.08	151.14	NS (0.094)	115.00	97.46	NS
Mean Number of Species per Plot	3.85	5.60	0.025	4.36	4.21	NS
(b) Habitat						
Mean Area per Plot of All Wetland Habitat (Ha)	20.75	27.97	0.003	21.53	21.91	NS
Number of Waterbodies per Plot	3.11	4.45	0.012	3.68	3.21	NS

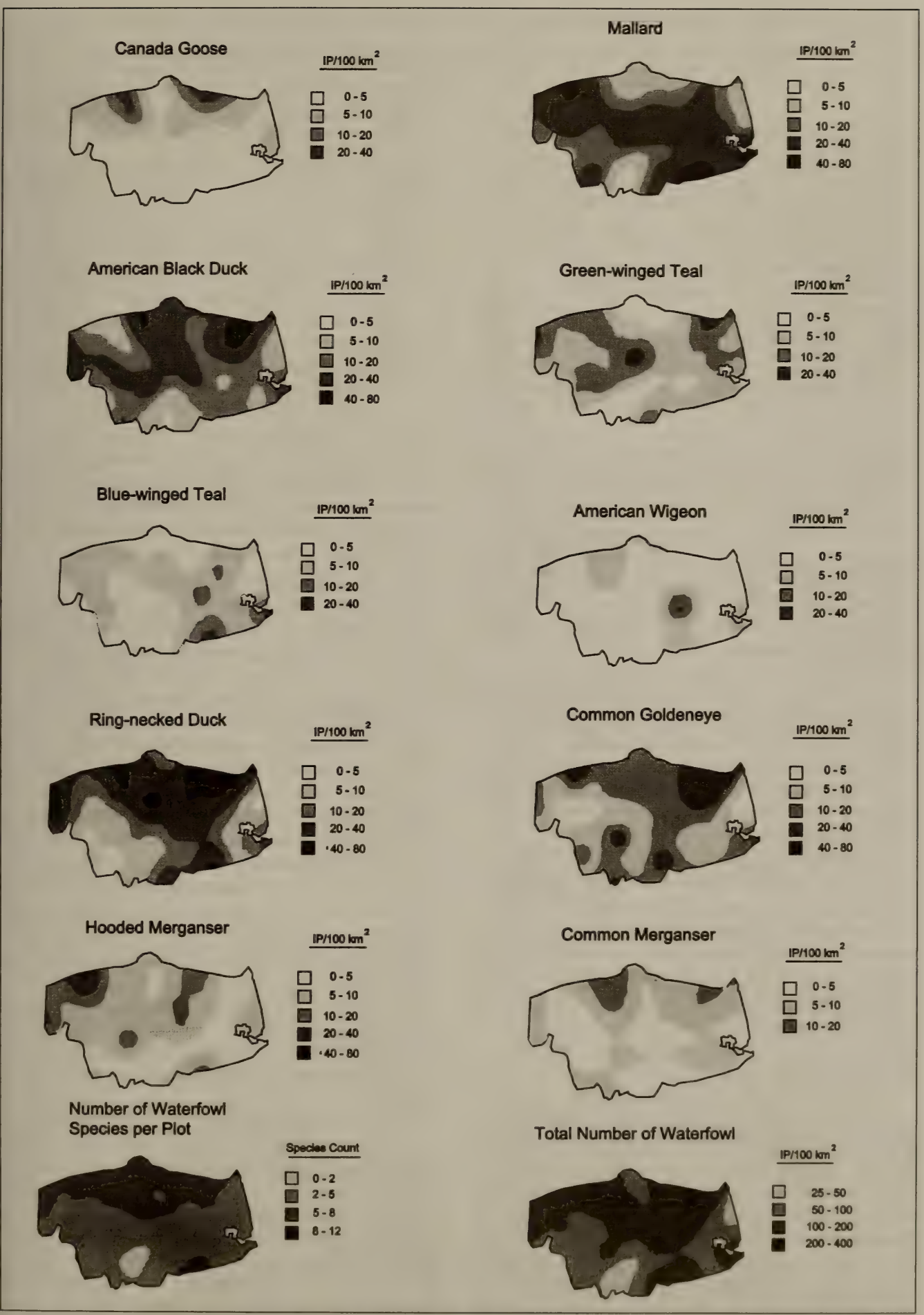

FIGURE 2. Contoured maps showing breeding densities of individual waterfowl species, overall breeding density, and species richness

TABLE 3. Comparisons between ecodistricts and between substrates of breeding densities of the major waterfowl species in the Clay Belt.

Classification	Ecodistrict			Substrate		
Division	No. 29	No. 30	Significance (p)	Clay	Moraine	Significance (p)
Species						
Mallard	25.51	20.00	NS	29.17	14.92	0.013
Ring-necked Duck	12.35	37.92	<0.001	20.95	17.05	NS
American Black Duck	13.81	29.47	0.008	16.39	18.00	NS
Common Goldeneye	8.85	21.25	<0.001	12.38	10.85	NS
Green-winged Teal	8.54	7.50	NS	8.45	9.30	NS
Hooded Merganser	6.69	6.67	NS	5.09	9.88	0.04
Blue-winged Teal	5.45	6.25	NS	6.48	3.29	NS
Common Merganser	2.88	6.67	NS	3.82	5.04	NS
Canada Goose	2.06	8.33	0.006	2.89	3.29	NS
American Wigeon	3.70	1.25	NS	3.70	1.55	NS

had high concentrations of Black Ducks and Ring-necked Ducks. No relationship with either substrate or ecodistrict could be demonstrated, probably due to the small numbers recorded. Common Mergansers have shown an affinity for rivers (McNicol et al. 1987; Rempel et al. 1997) in the Boreal Forest and their distribution in the Clay Belt may reflect the concentration of tributaries that converge toward the Moose River in the northeast.

Small numbers of Canada Geese were found north of Lake Abitibi and Highway 11 in habitat showing strong muskeg elements of the Hudson Bay Lowlands which lie immediately to the north, and are the centre of the breeding range of the Southern James Bay Population of Canada Geese (Raveling and Lumsden 1977). Breeding density was significantly higher in Ecodistrict 30.

American Wigeon were uncommon and not recorded in sufficient numbers to define distribution or determine regional differences. The species prefers larger permanent marshes with much open water (Palmer 1976) and shows an affinity for lake estuary marsh in the Clay Belt (Rempel et al. 1997). Northern river deltas held the highest breeding densities of this species (Bellrose 1980).

Overall Waterfowl Distribution and Species Richness

Contoured maps of total breeding pair density of waterfowl and numbers of waterfowl species per plot (Figure 2) indicated that both overall waterfowl density and species richness were higher in the north. However, there was a significant relationship only between ecodistrict and species numbers (higher in Ecodistrict 30; Table 2). This may be an "edge effect" (i.e., higher habitat diversity) due to the intergradation with the Hudson Bay Lowlands immediately to the north. Another area of higher species richness and density occurred around Timmins and Lake Abitibi near the south-eastern edge of the Clay Belt, possibly reflecting greater habitat diversity where the Clay Belt grades into the Great Lakes-St. Lawrence Forest Region. Lowest species richness and density occurred around the southwestern edge in a very sandy section of the Chapleau Plain.

Comparison with Other Studies

Our survey showed that waterfowl breeding in the Clay Belt were not distributed uniformly. Species richness was significantly higher towards the north, particularly in Ecodistrict 30, and total numbers of breeding pairs showed a similar tendency. This gradient towards the north was significant for four species (Canada Goose, Black Duck, Ring-necked Duck, and Common Goldeneye), all of which are characteristic of boreal habitats and seem to respond to physiography, particularly the amount of wetland habitat. Mallards and Blue-winged Teals were concentrated in a northwest-southeast strip bisecting the Clay Belt which correlates with the distribution of clay substrate. These species are more broadly distributed in other habitats to the south and west and may be responding either directly or indirectly to the higher productivity associated with clay (Merendino and Ankney 1994). Other species, such as the American Wigeon and the Green-winged Teal, did not exhibit either of these patterns and instead may be responding to distributions of very specific habitat types.

Initial comparison of our results with those of earlier surveys (Table 1) indicated substantial differences. However, the previous surveys only covered part of the Clay Belt and locations of survey plots in earlier studies strongly influence the results. The Clay Belt plots used by Dennis (1974) were mostly in the relatively wetland-rich Ecodistrict 30 and other areas north of Highway 11, where one would expect a higher total breeding density than the average from the present survey. Conversely, the survey by Ross (1987), that yielded a relatively low total

breeding density, was restricted to a 100 × 100 km block in the south central portion of the Clay Belt and included areas with the lowest breeding densities in this study. These relationships hold for three of the most common species. Black Duck and Common Goldeneye densities were highest in the Dennis (1974) survey while Black Duck density was lowest in the Ross (1987) count. Both species demonstrate the previously noted north-south density gradient. Densities for the Mallard, which did not show the north-south gradient, differed little among surveys. This implies that there have not been major changes in the Clay Belt populations of these three species since 1973. Of the more abundant species, only the Ring-necked Duck showed results [lowest count in the Dennis (1974) survey] that are not explainable by their present distribution.

Total waterfowl breeding density is slightly higher on the Clay Belt than on the surrounding boreal forest characterized by exposed Precambrian Shield although the ranges of values partially overlap [Clay Belt (Table 1): 91.8–126.1 IBP/100 km^2 vs. Exposed Shield (Ross 1987): 75.0–107.8 IBP/100 km^2]. Species composition, however, differs considerably. Generally, dabblers such as the Mallard, and Blue-winged Teal are more common in the Clay Belt whereas the mergansers attain higher densities on the exposed shield; goose numbers are minimal in both areas. The higher density of wetlands in the exposed shield appears to compensate in part for the higher productivity of individual wetlands in the Clay Belt (Ross 1987). The Hudson Bay Lowland immediately to the north supports, lower densities of ducks (approx. 37 IBP/100 km^2; Ross, unpublished information) but higher numbers of geese (5–13 IBP/100 km^2 for Canada Geese). Overall the contribution of the Clay Belt to northern Ontario duck numbers is essentially proportional to its area.

Conservation Implications

Better understanding of distribution of waterfowl and characteristics of their breeding habitat allows more focussed and effective conservation actions. Areas being considered for acquisition and protection can be priorized based on waterfowl breeding density and species richness. Numbers of waterfowl potentially at risk due to large-scale developments, (e.g., forestry, hydro-electric dams, and mining) can be determined and remedial action plans prepared. Furthermore, some insight can be gained into the effects of specific management actions. For example, efforts to increase the amount of wetland habitat may well show colonization by species such as Black Duck, Ring-necked Duck, Common Goldeneye, and possibly Canada Goose. If this managed habitat also has a rich clay substrate, one can also expect an increase in Mallards (and possibly Blue-winged Teal); however, this may lead to competitive interaction between Black Ducks and Mallards (Merendino and Ankney 1994). Target species and substrate type should be carefully considered in determining site locations for habitat management activities in the Clay Belt.

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Resilience of Foothills Rough Fescue, *Festuca campestris*, Rangeland to Wildfire

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A three year monitoring program evaluated the effects of a December 1997 wildfire in southwest Alberta, on Foothills Rough Fescue grassland species composition, ground cover, herbage production, and forage quality. Changes in species abundance included a reduction in grass cover ($p<0.10$) after burning. Rough Fescue also increased seedhead production during the second year after fire ($p=0.08$). Relative to the unburned area, graminoid production declined ($p<0.05$) by approximately 40% with burning, while forb production was unaffected. By the second growing season, live plant cover and herbage production had recovered on the burned area. The forage quality of individual Foothills Rough Fescue plants was greater on the burned area, with the greatest increase in crude protein in 1998 ($p<0.10$), and energy and total digestibility in 1999 ($p<0.05$). Increased quality may be linked to the level of forage production, as well as a fire-induced delay in plant phenology. Although soil erosion appeared to be minimal, there was an increase in exposed soil and a corresponding decline in litter and mulch cover ($p<0.05$). Greater nitrogen levels ($p=0.051$) were found in creeks downstream of the burn area during 1998, indicating some nutrient losses may be attributed to the fire. Although the grasslands examined displayed considerable resilience to this severe wildfire, favourable recovery was probably linked to the high precipitation during 1998, when summer rainfall was 48% above average.

Key Words: Foothills Rough Fescue, *Festuca campestris*, forage quality, precipitation, production, resilience, Alberta

Foothills Rough Fescue (*Festuca campestris* Rydb.) grasslands are well-adapted to fire, having a historical fire return interval of 5–10 years (Wright and Bailey 1982). During the last century, however, fragmentation of rangeland landscapes and fire suppression is thought to have enhanced the risk of severe fires by lengthening fire return intervals and increasing fuel accumulation during the burn intercession. Antos et al. (1983) concluded that Foothills Rough Fescue grasslands were best adapted to moderate frequency fire (e.g., every 6 years).

From January of 1997 through August of 2000, eight known wildfires were documented in the Fescue Prairie region of Alberta affecting nearly 33 500 ha, with at least five of these greater than 400 ha (Barry Adams, personal observation). This trend prompted concerns over the ability of these grasslands to recover from wildfire, particularly those following the prolonged absence of fire. Native rough fescue grasslands may be less tolerant of infrequent fire due to the increased severity of burning associated with litter accumulation. Rough fescue in particular, is of value to the ranches in the region because of its role in providing a practical and economical source of fall and winter grazing (Willms et al. 1993), as well as habitat for wildlife.

Although several studies investigating the response of fescue grassland to fire have been conducted, these typically involve Plains Rough Fescue (*Festuca hallii* (Vasey) Piper) grasslands in the Aspen Parkland of Alberta and Saskatchewan (Bailey and Anderson 1978; Anderson and Bailey 1980; Redmann et al. 1993; Gerling et al. 1995). Furthermore, these studies examine areas burned under prescription rather than wildfire. Antos et al. (1983) examined changes in species composition following a small (49 ha), uncontrolled wildfire in July within a Foothills Rough Fescue-Idaho Fescue (*Festuca idahoensis* Elmer) plant community in Montana.

As a result of concerns associated with increasingly common wildfire events in Alberta and the lack of information on their ecological impacts, a research plan was formulated to assess Foothills Rough Fescue grassland recovery following a large-scale wildfire that occurred in December 1997. Initial inspection of the burned area indicated that many rough fescue plants had been heavily damaged and/or killed, presenting a unique opportunity to examine the impact of a dormant season fire on the resilience of these grasslands. Specific objectives of this project were to determine the short-term (2-3 year) impacts of the fire on: (1) plant community composition and ground cover, (2) above-ground net primary production, and (3) rough fescue forage

quality. A secondary objective was to investigate the area for soil erosion.

Methods

Study Area

The study area was burned by a wildfire on 14 December 1997, covering 220 km² southwest of Granum, Alberta (113°50″W; 49°45″N) within the Fescue Prairie Ecoregion (Strong 1992). The fire began around 11:00 and traversed 33 km in under four hours. The fire was preceded by a dry autumn and aided by sustained winds of 30–40 km/hr, gusting to 70 km/hr. Weather conditions at the time of the fire were unusual for December, with a maximum mid-day temperature of 13°C (10°C above average) and relative humidity of 17% (Tymstra 1998*). Although detailed fuel-load data are unavailable for the burned area itself, litter loads adjacent to the burn averaged nearly 900 kg/ha. Approximately 83% of the 21 600 ha burn affected Foothills Rough Fescue grasslands. The economic and social impacts of this fire on the ranching community within the region were widely publicized at the time.

A fire intensity assessment prepared by Tymstra (1998*) described the Granum fire as extremely hot with a head fire intensity ranging from 10 000 to 20 000 kW/m². Tymstra (1998*) further concluded that the average rate of fire spread (~10 km/hr) was one of the greatest documented for grassland fires in Canada.

Topography of the area varied from steep foothills to gently sloping terraces, with occasional flat valley bottoms. Elevations range between 1 000 and 1 500 m. Native grasslands are dominated by mid to late successional Foothills Rough Fescue-Parry Oatgrass (*Danthonia parryi* Scribn.) communities, interspersed with riparian vegetation along wetlands and streams, and xeric grasslands dominated by Idaho fescue and Parry Oatgrass on sites with shallow or poorly developed soils. In some areas, livestock grazing has resulted in an increase in introduced species such as Kentucky Bluegrass (*Poa pratensis* L.) (Willms et al. 1995, 1996). The dominant soil type is an Orthic Black Chernozem (Johnston et al. 1971).

Field Procedures

In May 1998, 10 sites were selected within Foothills Rough Fescue-Parry Oatgrass (*Festuca-Danthonia*) communities for monitoring, with eight situated along the perimeter burn as paired burned-unburned sampling sites, increasing the likelihood of evaluating vegetation responses to the fire itself. All paired sites were located on a uniform ecosite (i.e., aspect and soils) and were intersected by a human-made (i.e., grader-bladed) fire boundary. This stratification helped ensure that vegetational differences between paired transects were caused by the fire rather than a naturally occurring difference in physical site characteristics. Two additional sites were sampled within the interior of the burn.

At each site, a 30-m linear transect was randomly established and permanently marked to facilitate resampling in later years. On each transect, ocular estimates of canopy cover were done on all plant species within 15 systematically placed 0.1-m² quadrats (Daubenmire 1959) at peak vegetative growth in June of each year. In addition, the cover of loose litter and mulch, as well as the amount of bare soil were estimated. Mulch was defined as the matted layer of fine organic material overlying mineral soil, consisting of heavily degraded litter in combination with fine roots from plants, either dead or alive (Dix 1960).

Herbage production was determined within four, 1.5 m by 1.5 m portable cages randomly set up along each transect. During the last week of August in each year, all current above-ground net primary production (ANPP) was clipped within a 0.5-m² quadrat in each cage. Cages were moved to new locations between years. All ANPP was sorted to graminoid, forb, and litter components, dried at 50°C for 3 days, and weighed to determine dry matter. Rough fescue seedhead counts were done the first week of August within 15, 1-m² quadrats nested over the Daubenmire quadrats along each transect to assess the potential for seed production in each year.

To evaluate the effect of burning on forage quality, individual rough fescue plants were randomly selected and harvested during the first week of August. In 1998 and 1999, five and eight plants, respectively, were clipped on each transect. After standing dead material was removed, plant samples were analysed for crude protein (CP), acid detergent fiber (ADF), and total digestible nutrients (TDN), as these variables are important for evaluating the quality of forage available to livestock and wildlife (Holechek et al. 1998). In the third growing season after burning, vegetation sampling was limited to seedhead counts, the evaluation of exposed bare soil, determination of ANPP, and litter mass.

Watershed-level impacts of the fire were assessed from water samples taken within three creeks that flowed through the burn area. Samples were taken immediately above and below the burn between 22 January and 23 March, 1998 during snowmelt. All samples were analysed for total suspended solids (TSS), total dissolved sediment (TDS), and nitrogen (N) (Eaton et al. 1995).

Data Analysis

Direct comparisons were made using paired t-tests between the burned and unburned transects along the fire boundary on species richness (number of species), the cover of major grasses including foothills rough fescue and the wheatgrasses (*Agropyron* spp.), bare soil, litter, and mulch. The wheatgrasses [Northern

(*Agropyron dasystachyum* (Hook.) Scribn.), Western (*Agropyron smithii* Rydb.), and Bearded (*Agropyron subsecundum* (Link) A.S. Hitchc.)] were pooled during sampling due to difficulty in identifying each species based on vegetative characteristics, particularly within the recovering burn area. Total legume cover was also assessed because these species constitute a key functional group responsible for N-fixation. Separate t-tests were done on the 1998 and 1999 data to evaluate the extent of recovery through time. Although data from the two transects in the interior of the burn could not be directly (i.e., statistically) compared with those from the burn perimeter, data from these sites were averaged for comparison to the other locations. Graminoid and forb ANPP, litter, and Rough Fescue seedhead counts, along with forage quality parameters, were also tested for burning effects in 1998, 1999, and 2000.

Results and Discussion

Growing Conditions

Precipitation the year after the fire was favourable for recovery, with the majority falling during the growing season (Figure 1). Precipitation in 1998 at the nearby Agriculture Canada research station near Stavely was 502 mm from May to August, with a total of 647.5 mm in 1998, 46% above the regional average reported by Environment Canada (unpublished data). These data corroborate records from a ranch situated within the burn area, where April through August rainfall totalled 538 mm, and annual precipitation totalled 771 mm. In 1999, growing conditions approximated the norm for the region, with a total of 285 mm from May to August and annual precipitation of 399 mm (Figure 1).

Landscape patterns of green-up were variable in 1998, with some areas developing rapidly, as evidenced by advanced vegetative growth and the emergence of Rough Fescue seedheads by early May. Plant development appeared to be particularly advanced at the perimeter of the burn, possibly due to increased soil temperatures associated with the removal of litter (Antos et al. 1983), which could hasten tiller development. In other areas, however, phenology was noticeably delayed. Variation in vegetation development is likely attributed to differences in ecosite conditions such as slope, aspect, and soils, as well as corresponding variation in fire behaviour across the landscape. General reconnaissance suggested that the slowest development occurred within the centre of the burn where the greatest evidence of fire intensity was observed both during the fire (i.e., in terms of flame length and rate of spread) and after the burn (i.e., surface disturbance). At these locations, intense heat may have penetrated more deeply into the soil, increasing damage to plant meristems and carbohydrate reserves by destroying plant tissue. Greater damage, in turn, would force plants to resume growth from perennating buds, slowing growth. In 1999, the phenological development of burned vegetation was uniform throughout the burned area and more similar to that of the adjacent unburned vegetation.

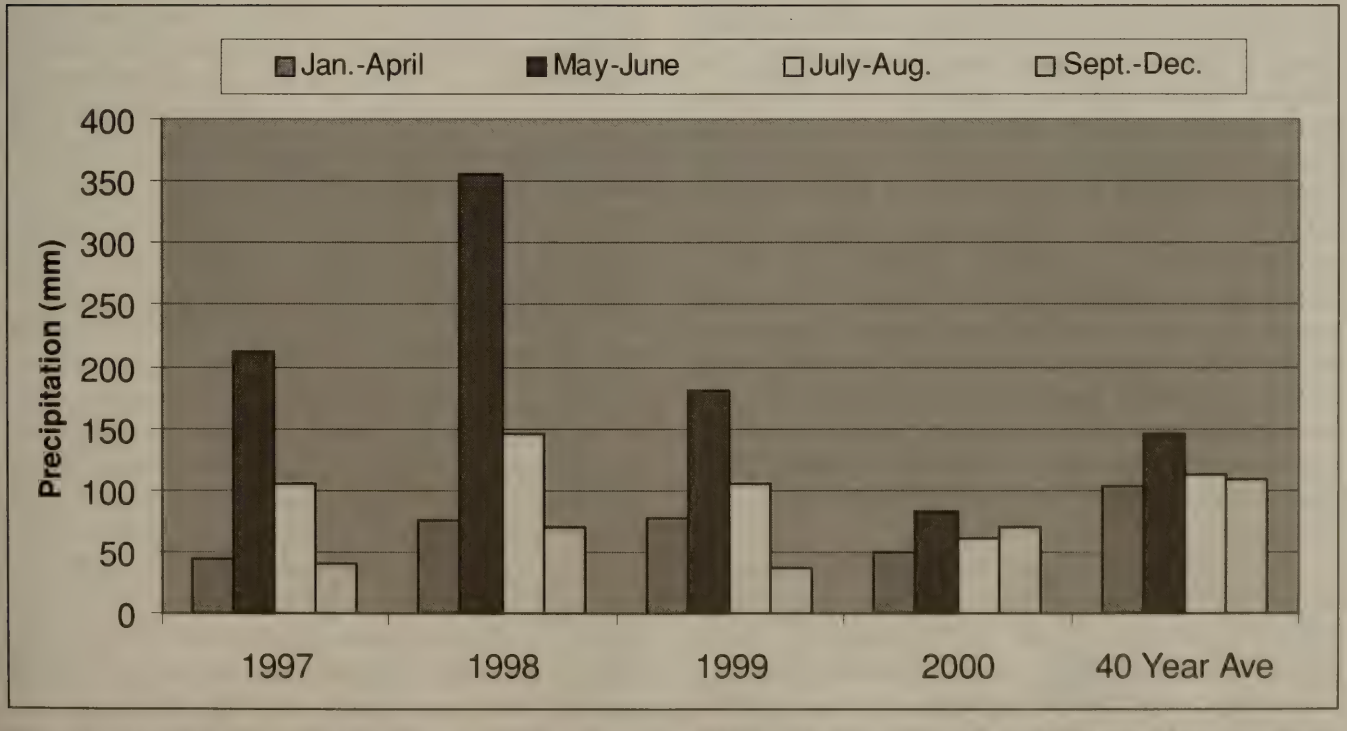

FIGURE 1. Yearly precipitation from January 1997 to December 2000 for the Agriculture Canada Stavely sub-station, located approximately 50 km north of the December 1997 wildfire, and comparison to long-term average precipitation from the Claresholm–Meadow Creek, Alberta climate station (Environment Canada, unpublished data).

Plant Species Abundance and Ground Cover

A summary of the differences in plant species abundance in 1998 and 1999 among each of the three sample locations (unburned, perimeter burn, and interior burn) is provided in Table 1. Differences between burned and unburned sites along the fire boundary are consistent with the notion that fire is effective in changing plant community composition (Daubenmire 1968).

Species richness (number/1.5 m^2) and overall diversity were similar between burned and unburned areas (Table 1). Although the cover of introduced species tended to increase by the end of the second growing season (Table 1: 1999 data), this change was not significant ($p > 0.10$). Concerns that Kentucky Bluegrass, due to its strongly creeping growth habit, might be more tolerant of fire and capable of invading areas where other plants had been removed by fire, did not appear to be substantiated. At two sites, Kentucky Bluegrass, and to a lesser extent Dandelion (*Taraxacum officinale* Weber), did increase indicating the expansion of invasive species may be linked to their presence and abundance within the community prior to burning.

Only total grass cover was reduced within the burned area relative to the unburned in 1998 ($p<0.10$; Table 1), with recovery by 1999. In comparison to the perimeter burn, grass cover was less but forb cover greater, within the burn interior. Species data indicate the forb response was likely due to an increase in legumes such as Lupine (*Lupinus argenteus* Pursh), Locoweed (*Oxytropis sericea* Nutt.), Buffalo Bean (*Thermopsis rhombifolia* R.Br.), and Vetchling (*Vicia americana* Muhl), all of which were more abundant in both sampling years (Table 1). Anderson and Bailey (1980) also found increases in 4 of 5 legume species associated with annual prescribed burning in Plains Rough Fescue grasslands of the Parkland in central Alberta. Other research has indicated legumes are well adapted to fire and increase following burning due to the termination of seed dormancy (Martin et al. 1975). Although not tested here directly, this factor may contribute to the observations made in this study and merit further investigation within Foothills Rough Fescue grasslands. Regardless of the mechanism, the increase in legumes is important in that they contribute nitrogen through symbiotic N-fixation, which may in turn, facilitate plant community recovery following fire.

Of the dominant grasses, Parry oatgrass appeared to decline the most the year after fire, followed by the wheatgrasses (Table 1). In contrast, sedges (*Carex* spp.) and Foothills Rough Fescue appeared to be resilient, with minimal difference in canopy cover across the fireline (Table 1). Rough fescue, however, had notably less cover at the interior of the burn relative to the perimeter. Assuming these transects had similar amounts of Rough Fescue as the other areas sampled (this assumption is supported by the presence of numerous dead fescue plants in the interior), burning may have been more severe at this location. The interior burn transects were generally located in areas where previous grazing may have been less intense, leading to greater litter accumulation. This interpretation is supported by the results of a 1990 range survey that described the grazing history of the interior burn area as very light, and was mapped as secondary range with considerable litter build up (Tannas 1990).

With the exception of Parry Oatgrass, all dominant grasses appeared to recover by the second year. The resilience of Foothills Rough Fescue following burning is inconsistent with other studies documenting fire-induced declines in rough fescue (e.g., Bailey and Anderson 1978; Antos et al. 1983). Most previous studies, however, have examined Plains Rough Fescue rather than Foothills Rough Fescue, which differ in morphology (Pavlick and Looman 1984), and presumably, their tolerance to fire. Mitchell (1957) suggested that the coarse stubble of rough fescue normally insulated perennating buds near the soil surface. With dry conditions, heavy stubble may allow the development of hot fires that burn into plant crowns as observed at the interior study locations. Antos et al. (1983) reported severe damage and high mortality of rough fescue on ungrazed sites where low fire frequencies allowed heavy litter accumulation, with three years needed for fescue recovery.

In this investigation, the wheatgrasses declined more than Rough Fescue despite being generally considered better adapted to tolerate fire due to their rhizomatous growth habit (Wright and Bailey 1982). Other studies of wheatgrass response to burning show varied results, although most research has been done in drier regions. In some, fall burning increases wheatgrasses (Wright 1974; White and Currie 1983), while in others, wheatgrasses decline (Erichsen-Arychuk et al. 2002). The response observed here could also be due to the presence of Bearded Wheatgrass within the stand, which lacks rhizomes and may be susceptible to fire.

Exposed Soil, Litter Cover, and Erosion Losses.

Cover of bare soil, litter, and mulch varied with sampling location (Table 1). In general, litter was significantly ($p<0.05$) less across the fire-line on the burned area from 1998 through 2000, with a corresponding increase in bare soil and mulch. By 2000, bare soil was no longer different between adjacent burned (3.4%) and unburned areas (1.4%), likely due to plant recovery and the re-accumulation of litter. Bare soil was significantly ($p < 0.05$) less across the fire boundary in 1999 but not 1998 ($p > 0.10$), and may indicate some drying and loss of protective mulch on the burned area between sampling periods.

TABLE 1. Mean canopy cover (%) of major plant species and functional groups at each location sampled in 1998 and 1999. Species listed only include those with a minimum average cover of 1%. Values in parentheses represent one SE for variables with significance tests.

	Canopy Cover — 1998			Canopy Cover — 1999		
Species	Interior Burn	Perimeter Burn	Unburned	Interior Burn	Perimeter Burn	Unburned
Agropyron spp.	2.1	6.5	9.1	12.4	15.5	11.9
Carex spp.	1.3	7	7.8	4.2	16.7	13.3
Danthonia parryi	0.4	0.8	9.2	2.5	4.1	13.7
Festuca campestris	3.6	10.1	11.6	25.5	22.4	23.5
Festuca idahoensis		4.1	5.7	0.2	13.9	9.3
Helictotrichon hookeri		0.9	0.8		5.2	5.1
Koeleria macrantha		0.8	2.5		3.3	1.8
Poa pratensis	0.2	0.3	0.5	3.3	3.2	0.6
Poa sandbergii					4.2	2.4
Stipa viridula	0.2			2.3	4.8	
Total Grass:	7.8	30.5 a (3.8)*	47.5 b (5.6)	50.4	93.4 a (4.8)	82.0 a (7.8)
FORBS:						
Achillea millefolium	1.2			7.1		0.1
Agoseris glauca	1	0.9	2.1	4.4	4.2	3.9
Androsace septentrionalis				6.2	0.6	
Anemone multifida	1.1	2.8	1.7	3.1	4	2.2
Aster laevis	0.6	0.3	0.1	3.1	0.1	0.6
Astragalus pectinatus		0.1	0.5	5.1	0.9	1.6
Cerastium arvense	0.1	0.2	0.8	0.5	1.4	1.2
Commandra pallida		0.3	0.7		1.5	1.6
Companula rotundifolia				2.9	0.5	0.5
Erigeron caespitosum		2.2	1.2		6.3	2.1
Galium boreale	1.7	2.6	1.6	5	4.2	4.7
Geum triflorum	1.6	0.1		2.2	0.3	
Heterotheca villosa		1	1.3	1	3.4	2.8
Liatris punctata		0.3	0.8		1.1	1.8
Lomatium dissecta	0.2	0.3	0.3	0.7	0.3	1.1
Lupinus argenteus	8.8	1.3	1.8	16.2	2.7	4.3
Oxytropis sericea		0.8	0.7		3.3	1.4
Phlox hoodii		0.1	0.7		0.4	1.2
Solidago missouriensis		0.1		0.7	2.8	0.9
Taraxacum officinale	0.1	0.3	0.4	0.4	0.7	0.3
Thermopsis rhombifolia	10.4	2.8	4.5	21.4	10.7	9.3
Tragopogon dubius	0.1	0.2	0.1	0.2	0.1	1.1
Vicia americana	0.6	1.3	0.4	0.1	2	1.3
Viola canadensis	0.7	0.1		0.4	1	
Zygadenus venenosus	0.1	0.9	0.2	0.6	1.3	0.1
Total Forb:	28.7	20.6 a (4.5)	22.2 a (3.6)	82.1	55.9 a (5.4)	46.8 a (5.6)
Legume Cover:	19.8	6.7 a (1.6)	8.5 a (1.8)	42.7	19.7 a (4.3)	18.5 a (3.9)
SHRUBS:						
Artemisia frigida		0.3	2		1.4	2.3
Rosa arkansana	2.7	0.5	0.2	3.9	1	0.5
Total Shrub:	2.7	0.8 a (1.2)	2.2 a (1.3)	3.9	2.4 a (0.6)	3.1 a (0.4)
INTRODUCED COVER	0.2	0.6 a (0.5)	0.9 a (0.4)	3.6	4.0 a (2.4)	1.0 a (0.5)
RICHNESS (no./1.5 m²)	17.5	23.3 a (1.8)	24.3 a (1.3)	21	27.8 a (1.4)	26.0 a (1.5)
SHANNON DIVERSITY	0.95	1.08 a (0.04)	1.08 a (0.04)	0.99	1.16 a (0.04)	1.14 a (0.04)
OTHER:						
Litter Cover	11.2	39.6 A (10.2)	91.7 B (5.8)	55.4	76.3 A (4.1)	97.9 B (1.7)
Mulch Cover	76	52.1 A (8.0)	7.5 B (5.6)	28.2	14.7 A (3.3)	0.0 B (0)
Bare Soil	11.9	5.4 a (3.6)	0.1 a (0.1)	15	6.6 A (1.4)	0.3 B (0.2)
Exposed Rock	1.3	0.8 a (0.4)	0.2 a (0.1)	1.2	0.5 a (0.3)	0.1 a (0.03)
Microphytic Cover		2.9 a (2.1)	0.5 a (0.3)		1.9 a (1.9)	1.8 a (1.7)

*Within a component and year, cover values across the fire boundary with different upper and lowercase letters are significantly different from one another at $p < 0.05$ and $p < 0.10$, respectively.

Overall, the greatest amounts of bare soil and mulch were evident at the interior burn, further supporting the notion that this area was more severely burned.

Potential for soil erosion was a serious concern to the local community and land administration agencies. Soil drifting was so severe on adjacent cropland immediately following the burn that emergency tillage was imposed. In contrast, there was little or no evidence of mineral soil loss on burned rangeland. Soil exposure was less than 1% on unburned areas, with 5.5 to 6.6% exposure on the perimeter burn and 11.9 to 15% for the interior burn during 1998 and 1999, respectively. In Foothills Rough Fescue grasslands, soil erosion by water tends to increase when soil exposure exceeds 15% (Johnson 1962; Naeth et al 1991); although soil exposure on the burned area increased, it failed to exceed this threshold.

Comparative assessment of water quality above- and down-stream of the fire indicated that although total suspended and dissolved solids differed little, greater nitrogen was present in water collected from creeks immediately below the burned watersheds (Table 2; $p = 0.051$). Thus, fire likely contributed to nitrogen loss during snowmelt and/or spring rainfall from the watersheds.

Herbage ANPP and Litter

Graminoid and forb ANPP followed patterns similar to that for plant cover (Table 3). In particular, graminoid production declined ($p < 0.05$) by about 40% across the fire boundary in 1998, but remained negligibly less in 1999, with full recovery in 2000. In contrast, forb production appeared to be greater on the burned area in the years after the fire (Table 3), although this difference was not statistically significant ($p > 0.10$). The greatest visible effect of burning in each year was at the interior burn, where a further decline in graminoid production and increase in forb production initially occured relative to the perimeter burn. Interestingly, this trend reversed in 2000, with graminoid and forb production apparently greater at the interior burn.

The initial decrease in graminoid ANPP after fire is consistent with other studies for both Foothills Rough Fescue (Jourdonnais and Bedunah 1990) and Plains Rough Fescue grasslands (Redmann et al. 1993; Gerling et al. 1995). Recovery of production in all these studies took at least two years. Redmann (1978) attributed declines in production following burning to increased plant water stress. However, the favourable precipitation during 1998 in the current study suggests the reduction may be from plant responses directly caused by fire rather than a change in soil water regime. Coupland (1974, as cited in Redmann 1978) also documented reduced productivity after fire in Mixed Prairie despite above-normal precipitation. Regardless of the mechanism, the magnitude of production decline observed here may be linked to the dormant season timing of the burn, as autumn fires are more detrimental than spring fires (Redmann et al. 1993).

Several other factors may contribute to the reduction in graminoid production. Although the plant communities examined were in good to excellent range condition at the time of the fire based on the composition of unburned areas, drought or heavy grazing prior to the fire may have increased stress on graminoids and reduced their vigor or winter hardiness. Additive negative effects on vegetation have been shown between defoliation and drought (e.g., Hendrickson and Berdahl 2002) and defoliation and fire (e.g., Bunting et al. 1998). Although the combined impacts of defoliation and fire have been investigated on Foothills Rough Fescue (Bogen 2001), that study examined defoliation after burning rather than before.

The unusually mild autumn preceding the Granum fire may also have allowed vegetation to continue development into December. Erichsen-Arychuk et al. (2002) documented variable grassland recovery in Dry Mixed Prairie landscapes following August wildfire under drought conditions, with landscape-based differences potentially due to the stage of plant development at the time of fire. Following burning, the reduction of insulation through the loss of litter and associated snow cover would result in colder soil temperatures in winter (Johnston et al. 1971), increasing the susceptibility of burned plants to freezing (Kowalenko and Romo 1998).

As expected, litter mass was markedly less ($p < 0.05$) on the burned area (Table 3). Although the favourable growth during 1998 increased litter on the burn by the end of 1999, it remained less compared to the unburned area, with this trend continu-

TABLE 2. Results of the analysis of water sampled from three creeks above and below the fire affected watersheds in 1998 and analyzed for total suspended solids (TSS), total dissolved sediments (TDS), and nitrogen (N).

	Mean per Sampling Location (SE):		Significance*:	
Variable:	Above Burn (n = 11)	Below Burn (n = 11)	T- statistic	Probability
TSS (ppm)	178.5 (44.5)	297 (152.4)	0.73	p = 0.482
TDS (ppm)	564 (56.4)	1010 (328.7)	1.42	p = 0.186
N (ppm)	1.15 (0.15)	3.88 (1.30)	2.22	p = 0.051

*Paired t-tests contrast samples collected from above and below the burned portions of the watershed.

TABLE 3. Mean (SE) current annual graminoid and forb production, as well as litter levels (kg/ha) within the unburned, perimeter burn, and interior burn locations in 1998, 1999, and 2000.

Component	Year	Unburned	Perimeter Burn	Interior Burn
Graminoid	1998	1466 (126) A*	940 (77) B	714
	1999	1596 (154)	1498 (226)	1220
	2000	966 (109)	844 (48)	1349
Forb	1998	439 (44)	545 (73)	682
	1999	453 (37)	621 (105)	921
	2000	110 (15)	133 (29)	292
Litter	1998	898 (69)	0 (0)	0
	1999	3351 (761) A	852 (98) B	662
	2000	2101 (381) A	908 (28) B	948

*Within a component and year, comparisons between burned and unburned means across the fire boundary represented by different letters are significantly different ($p < 0.05$).

ing into 2000 (Table 3). Litter is important for conserving soil water and maintaining herbage production (Weaver and Rowland 1952; Willms et al. 1986). Antos et al. (1983) found the loss of litter after fire increased soil temperatures, reducing the near-surface effective water regime. Fluctuations in litter, even on the unburned area (Table 3), indicate how rapidly this variable can change. Litter is lost as a result of fire, herbivory, microbial decomposition, and weathering, and is affected by grassland species composition (Facelli and Pickett 1991). Willms et al. (1996) found 23% of total biomass disappeared between fall and spring on good condition rough fescue grassland, while 56% disappeared from stands dominated by forbs and introduced grasses. Given the slow re-accumulation of litter in this study, it appears several years are needed for litter re-accumulation following the Granum fire.

Rough Fescue Seedhead Production

Burning increased ($p < 0.10$) Rough Fescue seedheads two years later, when seedhead densities on the burned area were more than twice that of the unburned area (Table 4). The delay in response following disturbance is similar to that found in other studies for Foothills Rough Fescue (Johnston and MacDonald 1967; Willms 1988). Gerling et al. (1995) found Plains Rough Fescue increased seedhead production the year following fire, but only when burned in spring or early summer (i.e., 1 June or earlier) of the previous year rather than in late summer or fall.

Burning may have increased seedhead production by the addition of nutrients to the soil or the loss of litter. Litter removal may trigger seedhead establishment through increases in photosynthetically active radiation (PAR) within the meristematic region of the plant crown (Willms 1988). The delayed response indicates that either plant stress immediately after burning inhibited reproduction the first year, or more likely, that there is a time lag needed for developing tillers to become reproductive, as determined by the new environmental (e.g., light and/or nutrient) conditions after fire. It should also be noted that seedhead production was generally greater on the unburned area in 1999 (19.5 ± 3.8) than in 1998 (2.9 ± 1.1) (Table 4). Thus, abundant seedhead production in 1999 on the burned area is due to the combined effect of favourable moisture during 1998, coupled with burning. The increase in seedheads reflects an important ecological adaptation of Foothills Rough Fescue to ensure this bunchgrass recolonizes areas of soil following burning, and thus, ensures its perpetuation within the plant community.

Rough Fescue Forage Quality

Burning positively affected the forage quality of Rough Fescue. In particular, crude protein and total digestibility increased, while acid detergent fiber (ADF) decreased (Table 5). However, between-plant variation was considerable, with only crude protein differing significantly ($p < 0.10$) across the fire boundary in 1998 (other variables had $p < 0.15$).

TABLE 4. Rough Fescue seedhead production on the three sampling areas from 1998 to 2000.

	Seedhead Densities — #/m² (SE):			Significance*:	
Year	Interior Burn	Perimeter Burn	Unburned	T- statistic	Probability
1998	0.2 (0.1)	1.1 (0.6)	2.9 (1.1)	2.21	$p = 0.11$
1999	56.2 (17.3)	42.0 (10.9)	19.5 (3.8)	2.64	$p = 0.08$
2000	0.4 (0.1)	0.1 (0.1)	0.8 (0.4)	1.73	$p = 0.18$

*Paired t-tests contrast data collected across the fire boundary (i.e. Perimeter Burn vs Unburned).

TABLE 5. Mean (SE) percent crude protein (CP), acid detergent fiber (ADF), and total digestible nutrients (TDN) of Foothills Rough Fescue plants sampled within the unburned, perimeter burn, and interior burn locations in 1998 (n = 5 per transect) and 1999 (n = 8).

Component	Year	Unburned	Perimeter Burn	Interior Burn
CP (%)	1998	7.20 (0.11) a *	8.40 (0.44) b	10.10
	1999	7.39 (0.29)	6.54 (0.36)	8.49
ADF (%)	1998	41.8 (0.7)	40.2 (0.5)	38.6
	1999	42.2 (0.4) A	40.9 (0.4) B	38.9
TDN (%)	1998	52.1 (0.5)	54.5 (0.3)	56.9
	1999	51.4 (0.3) A	53.4 (0.3) B	56.4

*Within a nutrient, comparisons between burned and unburned areas across the fire boundary represented by different uppercase ($p < 0.05$) or lowercase letters ($p < 0.10$) differ significantly.

When larger sample sizes of plants were used in 1999, energy and total digestibility were greater ($p < 0.05$), and ADF lower ($p < 0.05$), within the burned area. Crude protein was unaffected ($p > 0.10$) in 1999, although it remained particularly high in plants sampled from the interior burn.

The initial increases in protein are similar to the changes reported for Plains Rough Fescue following fire (Redmann et al. 1993) and burned Bluebunch Wheatgrass (*Agropyron spicatum* (Pursh) Scribn.) (Willms et al. 1981). Improved quality may be due to nutrient release into the soil following burning (Daubenmire 1968) or reduced competition on the burned area corresponding with a decline in live plant cover (Table 1). Increased quality may also stem from a delay in plant phenology throughout the summer, which would result in greater comparative quality at a fixed date of sampling. Delayed phenology of rough fescue grassland following autumn burning was documented by Redmann et al. (1993), as was an associated increase in N concentration.

Conclusions

The 1997 Granum wildfire in Fescue Prairie had variable effects on Foothills Rough Fescue grassland plant species abundance and ground cover, herbage production, and forage quality, as determined by differences between the unburned and perimeter burn locations. Grass cover and production declined the year after fire, but recovered by 1999, likely as a result of the above average precipitation in 1998. Drought after burning may have had an additive detrimental impact on vegetation recovery, particularly in the absence of litter to conserve soil water. Declines in production also coincided with increases in the forage quality of Rough Fescue. The observed responses highlight the impacts of dormant season wildfire on Foothills Rough Fescue grasslands, including the resilience of the dominant species. Additionally, it should be noted that although species richness and diversity were not increased by fire in this investigation, there was evidence that fire was effective in increasing the abundance of forbs, particularly legumes. Thus, the importance of occasional fire in maintaining biodiversity should not be discounted within these grasslands.

For many ranches affected by the fire, the need to restore litter through conservative grazing may seem to conflict with their natural concern about grass litter as a fire hazard. Balancing the need for litter to conserve water and protect the range resource, yet prevent excessive fuel loading, will be an ongoing question for land managers to address. Fortunately, the more enduring negative impacts of fire appear to be confined to a relatively small area. The results of this project should also be of interest to the managers of protected areas where grazing and the normal cycling of biomass by large herbivores and fire have been altered from their natural process on the landscape.

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Survival, Fates, and Success of Transplanted Beavers, *Castor canadensis*, in Wyoming

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Beaver (*Castor canadensis*) through their dam building activities, store water, trap sediment, subirrigate vegetation, and subsequently improve habitat for fish, wildlife, and livestock. Many landowners realize the benefits that Beaver can bring to a riparian area and are interested in using them to improve this habitat. From 1994 to 1999 we trapped and relocated 234 Beaver to 14 areas throughout Wyoming to improve riparian habitat and create natural wetlands. We attached radio transmitters to 114 Beaver and subsequently determined movements and mortality of released Beaver, and the overall success of our releases. Mortality and emigration (including transmitter failure) accounted for the loss of 30% and 51%, respectively, of telemetered Beaver within 6 months of release. Kaplan-Meier survival estimates were 0.49 (SE = 0.068) for 180 days and 0.433 (SE = 0.084) for 360 days, and did not differ significantly between age classes. On average, 17 Beaver were transplanted to each release site, and at 11 locations, in an attempt to augment single Beaver that had become established and increase transplant success, we transplanted Beaver in two or more years. Success of an individual Beaver's relocation was unrelated to any of the variables we tested, although 2–3.5 year-old Beaver had higher average success (measured in days of occupancy at the release site) than older animals. Animals < 2 years old had 100% mortality and emigration losses within 6 months of release. High predation and mortality rates of our released Beaver may be due to habitat (our streams were shallow with no ponds and provided little protection) and extensive predator communities. We established Beaver at 13/14 of our release sites and they eventually reproduced. Our results show that Beaver can be relocated successfully but losses from mortality and emigration need to be considered and planned for.

Key Words: Beaver, *Castor canadensis*, transplanting, reintroduction, translocation, predation, Wyoming

Beaver (*Castor canadensis*) alter riparian-stream ecosystems through their woodcutting and dam-building activities. Beaver dams create a lentic habitat in an otherwise lotic system. These ponds retain sediment and organic matter in the channel, create and maintain wetlands, modify nutrient cycling and decomposition dynamics, modify the structure and dynamics of the riparian zone, alter hydrologic regimes (Butler 1991), and influence the character of water and materials transported downstream (Naiman et al. 1988). The resultant habitats are rich mosaics of diversity that are beneficial hydrologically (Hanson and Cambell 1963; Rabe 1970; Johnson et al. 1992), biologically (Jenkins and Busher 1979; reviewed by Hill 1982; Olson and Hubert 1994; Brown et al. 1996; McKinstry and Anderson 1999; McKinstry et al., 2001), and socially (Naiman et al. 1988). It is estimated that Beaver have been extirpated from over 25% of the streams in Wyoming, and in many streams where they are still present their numbers have been reduced to where they are ecologically absent (McKinstry et al. 2001). The elimination of Beaver from portions of its historic range has been cited as a major influence on the structure and patterns of vegetation in these systems (Neff 1957; Barnes and Dibble 1986; Naiman et al. 1986; Nummi 1989; Kay 1994; Nolet et al. 1994).

Throughout the intermountain west, interest has been expressed in improving riparian areas for wildlife, livestock, and humans (Apple et al. 1985; McKinstry and Anderson 1999; McKinstry et al. 2001). Beaver, through their dam building activities, can increase water storage, reduce sedimentation, and improve vegetation communities (Naiman et al. 1988), all of which are valuable to many landowners. Livestock are also attracted to Beaver-influenced areas for water, shade, and vegetation that remains green after upland forage has dried out. Forage production near these wetlands is often two to three times higher than comparable upland ranges (Apple et al. 1985; Chaney et al. 1991: 31). Many states have undertaken Beaver transplant programs to improve riparian areas (Smith 1980; Hill 1987; Butler 1991; Collins 1993; Vore 1993; McKinstry and Anderson 1997; McKinstry 2001) and managers with the Wyoming Game and Fish Department (WG&FD) decided to investigate the feasibility of a Beaver relocation program in areas where beaver have not recolonized due to isolation from dispersing populations and poor habitat conditions.

In 1994 we initiated research to (1) document the

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effects of Beaver on riparian areas in Wyoming (reported in McKinstry et al. 2000; 2001), (2) assess Beaver management concerns from both private and public landmanagers (reported in McKinstry and Anderson [1999]), and (3) evaluate a Beaver reintroduction project for the purpose of wetland creation and riparian improvement. Our objectives in this paper are to examine survival, mortality, emigration, and success of Beaver translocated in Wyoming for the purpose of riparian restoration.

Study Area

Beaver were trapped at 33 various locations in Wyoming (described in McKinstry and Anderson 1998) and translocated to 14 different 1st-3rd order streams (< 0.283 m/sec) throughout Wyoming (Figure 1, Table 1). All drainages were walked a minimum of 3 km in both directions from the proposed release site to document any past or current Beaver activity. At 13 of the release sites, old Beaver sign (20–100 yrs) was present but we found no fresh activity. At the remaining site, Breteche Creek, prior Beaver activity was not found. All release sites had sufficient vegetation to support Beaver. Four streams were ephemeral and dry in early August each year that we checked them (1993–1999), the remainder were perennial and carried water year-round (Table 1).

Methods

Beaver were trapped using snares and Hancock traps (McKinstry and Anderson 1998) from areas where they were causing damage to landowners (primarily irrigation conflicts) (30 sites) or where they were so plentiful that selective removal would not significantly impact the habitat (3 sites). All Beaver were trapped from colonies that were dam and lodge builders (creek Beaver) as opposed to bank-denning non-dam builders (river Beaver). We felt that these animals would be more likely to create the desired habitat.

We began trapping after ice-off in the spring (usually early to mid May) and concluded trapping by the second week in October, depending on snow and ice conditions. All traps were set between 1600 h and 1900 h each day and were checked by 1000 h the following morning to minimize the time that animals spent in traps. On average we set 17 traps/night/trapper; more than that and it was difficult to get them checked by 1000 h and find them in the

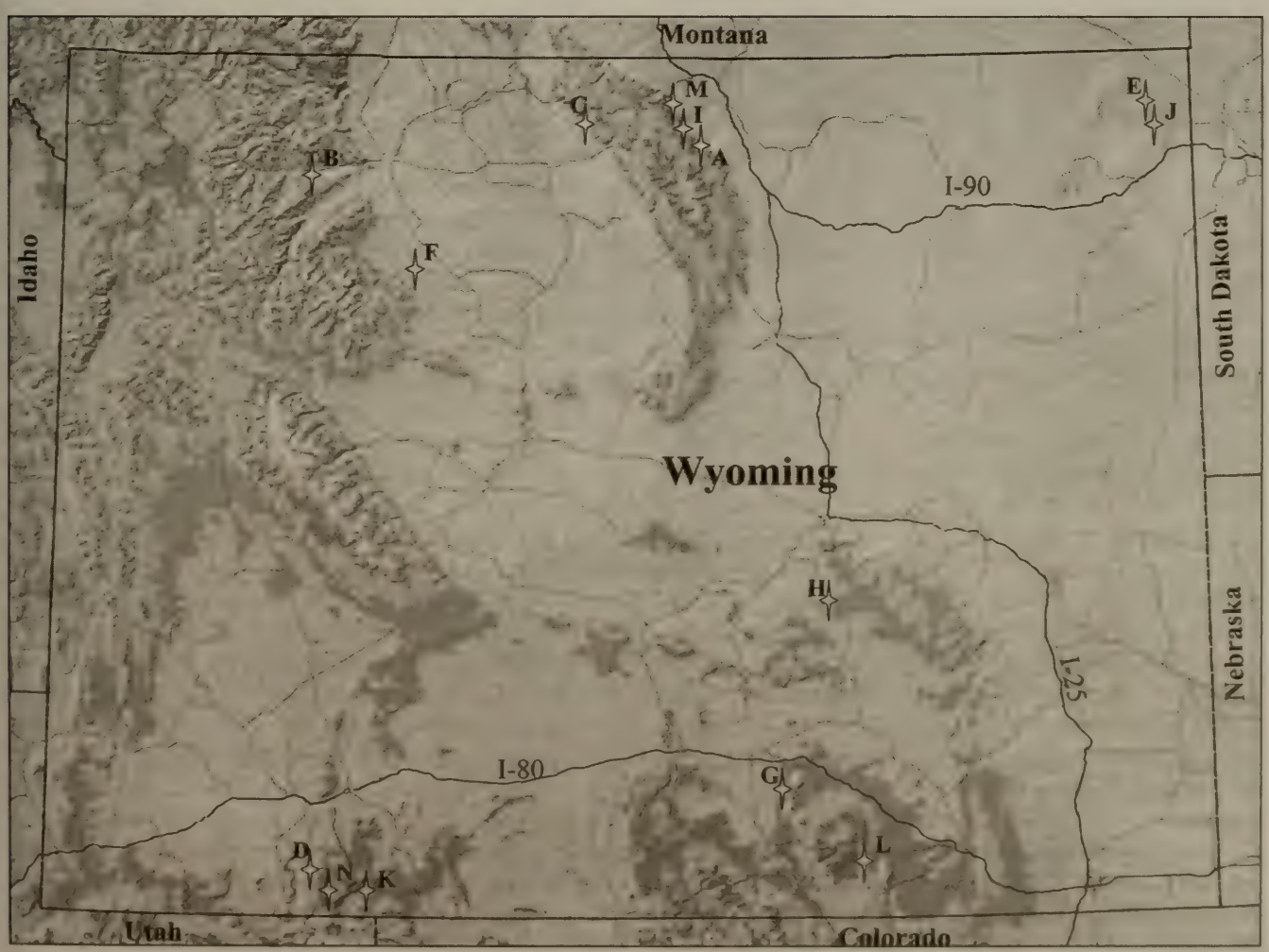

Figure 1. Beaver relocation sites in Wyoming. Letters correspond to release site locations described in Tables 1 and 2.

TABLE 1. Latitude and longitude, dominant vegetation, and stream classifications (using Rosgen's [1994] classification) for Beaver release locations in Wyoming. Letters for release sites correspond with locations in Figure 1.

Stream Name (nearest town)	Latitude, Longitude	Dominant Vegetation	Stream Classification
(**A**) Bear Gulch (Story)	44°31′46″N, 106°53′11″W	Aspen and cottonwood	DA5
(**B**) Breteche Creek (Cody)	44°24′36″N, 109°23′28″W	Aspen and cottonwood	A4
(**C**) Bush Creek[a] (Shell)	44°27′41″N, 107°37′30″W	Cottonwood	A4
(**D**) Currant Creek (Rock Springs)	41°12′55″N, 109°22′20″W	Willow	G5
(**E**) Deep Creek[a] (Sundance)	44°47′29″N, 104°20′41″W	Gambel's oak and aspen	C5
(**F**) Ennos Creek (Thermopolis)	43°54′50″N, 108°54′14″W	Willow	B4
(**G**) Lake Creek[a] (Saratoga)	41°28′16″N, 106°38′20″W	Narrowleaf cottonwood (*Populus angustifolia*) and willow (*Salix* sp)	B4
(**H**) Little Red Creek (Casper)	42°42′55″N, 106°23′48″W	Cottonwood	F4
(**I**) Prairie Dog Creek (Big Horn)	44°35′36″N, 106°54′30″W	Aspen and cottonwood	A5
(**J**) S. Pine Creek[a] (Sundance)	44°44′29″N, 104°20′30″W	Scrub oak and common chokecherry (*Prunus virginiana*)	F6
(**K**) Red Creek (Rock Springs)	41°04′01″N, 109°02′30″W	Engelmann spruce (*Picea engelmannii*) and cottonwood	F5
(**L**) Spring Creek (Centennial)	41°12′59″N, 106°07′44″W	Willow	F5
(**M**) Trabing Creek (Big Horn)	44°36′01″N, 106°58′59″W	Aspen and western hawthorn (*Crataegus succulenta*)	A4

[a]streams were ephemeral and dry by early August each year we checked (1993–1999)

thick willows where we were trapping. Beaver were sexed through cloacal examinations (Larson and Taber 1980:163), weighed to determine age class (kit, yearling, sub adult, and adult), and ear tagged in both ears with small monel ear tags for identification. Beaver were held up to five days post-capture in a 2.2 by 3.1 m cage that allowed them free access to water; this was necessary since we only caught a few (<3) animals each day and we wanted to move them as a group to the release site which was always >160 km away.

Forty-six Beaver (range 11–31 kg) were implanted with Advanced Telemetry Systems (ATS, Isanti, MN) model 17 internal telemetry transmitters using techniques described by Davis et al. (1984). Implanted Beaver were monitored for a minimum of 24 hours post surgery prior to release (Davis et al. 1984). Beginning in 1998, 67 Beaver (range 10–25 kg) were outfitted either with tail collars (8 Beaver) or transmitters mounted on the tail using modified ear-tag transmitters (59 Beaver) (Rothmeyer et al. 2002) in an attempt to reduce logistical problems associated with surgeries conducted in the field (e.g., cost, time, sterility concerns). All radio transmitters were equipped with 24-hour mortality sensors. Animals were released after 1500 hours in an attempt to decrease predation during daylight hours.

Beaver were monitored for movements and mortality for 2 days after release and approximately every 2 to 4 weeks thereafter. Mortality dates were calculated as the mid-date between the date found and the date of last-live location. At all release sites, streams were walked (minimum of 5 km) and flown (minimum of 10 km) in both directions 3 months after release to determine if Beaver were established. In four instances non-transmittered Beaver became established, and walking the streams allowed us to look for evidence of tree cuttings or dam construction and thus determine if non-telemetered Beaver were active. Since we were interested in using Beaver to improve habitat within 3 km of the release sites (usually headwater areas), we defined emigration as Beaver that moved further than 3 km from the release site. Beaver moving >5 km from the release sites were not monitored unless they built dams and lodges and remained stationary.

Cause of mortality was determined through physical examination of hair and scat samples found at the kill site (Moore et al. 1974), bite marks and subcutaneous bleeding (indicates animal was alive when bitten) on Beaver carcasses, track marks (O'Gara 1978), and, beginning in 1998, DNA analysis of hair and scat samples. Dr. Elizabeth Williams, Pathologist at the Wyoming State Veterinary Lab, performed lab work and necropsies. Tom Moore and Deedra Hawk, Forensic Supervisor and Research Associate, respectively, Wyoming Game and Fish Department, examined hair and scat samples.

We used a z test (Jandel Scientific 1994) to test proportional differences in captures of males versus females. For estimates of survival we used Kaplan-Meier product limit estimators (as reviewed by White and Garrott 1990) for both 360 and 180 day survival rates. We used the Kaplan-Meier approach since our data was staggered entry and we had con-

Table 2. Fates of introduced Beaver by release location. Letters in () correspond to release sites in Figure 1 and descriptions in Table 1.

	Predation							# Released		
	Coyote	Black Bear	Grizzly Bear	Mountain Lion	Human	Unknown[a]	Unknown Mortality[b]	With Transmitters ♀:♂:unknown[c]	Without Transmitters ♀:♂:unknown[c]	Total ♀:♂:unknown[c]
(A) Bear Gulch[d]	0	0	0	0	1	0	0	0:1:0	1:2:0	1:3:0
(B) Breteche Creek	5	0	4	0	0	1	0	6:6:0	2:3:2	8:9:2
(C) Bush Creek	1	0	0	0	0	0	0	2:3:0	5:5:0	7:8:0
(D) Currant Creek	3	0	0	0	0	0	2	5:7:0	3:4:0	8:11:0
(E) Deep Creek	0	0	0	0	0	0	0	1:2:0	4:3:0	5:5:0
(F) Ennos Creek	0	0	0	0	1	1	1	8:8:0	2:7:3	10:15:3
(G) Lake Creek	1	0	0	0	0	0	1	5:7:0	9:4:1	14:11:1
(H) Little Red Creek	1	1	0	0	0	3	5	6:11:0	4:7:4	10:18:4
(I) Prairie Dog Creek	0	0	0	0	0	0	0	1:1:0	0:1:0	1:2:0
(J) S. Pine Creek	0	0	0	0	0	0	0	2:1:0	0:4:0	2:5:0
(K) Red Creek	0	3	0	0	0	1	1	8:6:0	4:4:1	12:10:1
(L) Spring Creek	0	0	0	1	0	1	0	2:2:0	0:8:0	2:10:0
(M) Trabing Creek	0	0	0	0	0	0	0	2:2:0	2:9:0	4:11:0
(N) Trout Creek	0	0	0	0	0	2	0	3:6:0	3:9:0	6:15:0
Total	11	4	4	1	2	9	10	51:63:0	39:70:11	90:133:11

[a]Cause of predation was undetermined
[b]Beaver died from undetermined causes
[c]Usually kits that could not be sexed
[d]Releases at this site failed due to conflicts with irrigation structures and some Beavers were retrapped

siderable loss of individuals due to emigration or transmitter failure. To model success of transplants we used both logistic and multiple regression (White and Garrott 1990). For our logistic regression models we coded each Beaver as either a 0 for failure (emigration or mortality) or a 1 for success (lived > 6 months, constructed a dam and lodge, and had the opportunity to reproduce). For multiple regression models we used the length of success (remained within 3 km of release site) in days as our dependent variable. We used weight, sex, age class, season of release (spring: May 9–June 15) or fall August 15–October 10), year of release (1994–1999), and number of cohorts released concurrently with each Beaver as our covariates. For age class we plotted weights and found natural distinctions in the three younger classes (kits, yearlings [1.0–1.5-year olds], and subadults [2.0–3.5-year olds]) and grouped all animals > 13.6 kg (4-year olds) as adults. Minitab (Minitab 2000), SigmaStat (Jandel Scientific 1994), and SAS (SAS Institute 1991) were used for all analyses.

Results

Snares and Hancock traps were used to capture 277 Beaver at 33 locations throughout Wyoming and we eventually transplanted 234 to the 14 release sites. The 43 remaining Beaver either died during trapping (n = 15), transporting (n = 13), or were lactating females (n = 15), which we released after capture. Trapping mortality was 10% for Hancock traps and 5.3% for snares, and was not significantly different ($z = -0.07$, $P = 0.94$, $df = 11$). Mortality from traps was due to becoming entangled in snares (n = 11) and being killed by predators while restrained in snares and Hancock traps (n = 4). Trapping success during our five years of trapping was 11.1 trap nights/Beaver or 9.0% (the probability of an individual trap's capture). Average weight of animals captured was 16.2 kg (range 2.4–31 kg, SD = 6.11) and there was no difference in proportion of males (0.42) or females (0.58) captured ($z = 1.23$, $P = 0.22$, $df = 122$). We transmittered 63 (55.3%) females and 51 (44.7%) males.

Of 114 Beaver trapped, equipped with a transmitter, and relocated, 34 (30%) died within 180 days ($\bar{x} = 43$ days, SD = 37.4) of release (Table 2). Another 7 Beavers (36% total mortality) died prior to the failure of their transmitters (181-503 days). Coyotes (*Canis latrans*) were responsible for at least 27% of all mortalities, followed by Black Bears (*Ursus americanus*) (10%), Grizzly Bears (*Ursus horribilis*) (10%), Mountain Lions (*Felis concolor*) (2%), and humans (5%). Another 22% (of all mortalities) died of unidentified predators and the remaining 24% died from undetermined causes. Within 180 days of release, 58 (51%) Beavers either emigrated > 10 km from the release sites and were not found

again, or developed faulty transmitters, which made them impossible to relocate.

The Kaplan-Meier survival estimates for all Beavers were 0.49 for 180 days and 0.433 for 360 days and did not differ between age classes (Table 3). Beavers that died lived for an average of 86 days (range 1–503 days, SD = 114.8) until death, however eight died within seven days of release. All Beavers (that we found), except one, died within 0.5 km of the release site (the exception was found 0.75 km upstream of the release site).

Twenty-three (19%) Beavers lived > 180 days and eventually built dams and lodges in the drainages where they were released. Additionally, a minimum of 10 (actual number could not be determined since we did not retrap Beavers after release) of the other 120 Beavers released without transmitters were also found with dams and lodges within 3 km of the release sites (some of these may have been Beaver with faulty transmitters, although we feel this was unlikely). We released an average of 17 Beaver at each of our sites in an attempt to get animals to establish. Beaver successfully established at 13 of the 14 release sites and, as of September 2001, the 13 sites were still occupied. At the unsuccessful site Beavers had conflicts with irrigation structures (e.g., damming irrigation ditches) and they were removed.

We were unable to identify any variables in our analyses that significantly influenced the probability of success for beaver relocations. P values were > 0.2 and R-squared values were < 0.10 for all variables and models tested. The 2–3.5 year old age class had greater average occupancy at a site (Figure 2), although this relationship was not significant (P = 0.225, df 3). All kits and yealings (n = 12) either died (n = 5) or emigrated (n = 7) from the release site prior to 108 days and none were observed constructing dams and lodges.

Discussion

Limited range of transmitters and transmitter failure may have influenced the number of animals we found after release (Rothmeyer et al. 2002), subsequently increasing the number of Beavers assumed to have emigrated. Advertised range of the internal transmitters was 0.5 km but we found that the range was usually limited to 200 m, and animals within dens were not located until we were within 50 m of the transmitter. Range of the tail-mount transmitters was better but never approached the 1-km advertised range. Walking up and downstream of the release site within 20 m of the creek bed was necessary to determine movements and mortality.

Animals emigrating or not found after release may have had higher survival rates but we believe this is improbable. More likely, these Beaver were killed and cached in holes and dens, or dragged out of range of receivers. Animals moving out of the vicinity of the release area may also have experienced higher predation rates due to increased exposure time and less time spent hiding in dense vegetation or constructing dens. Beavers, sympatric with Black Bears on islands in Lake Superior traveled shorter distances from water than those found on islands where bears were not present, posssibly a direct attempt to avoid predation (Smith et al. 1994). Survival estimates for unexploited (i.e. untrapped) adult beaver are generally 0.80 (Boyce 1974; Bergerud and Miller 1977; Bishir et al. 1983) but these animals have ponds and lodges for escape. High mortality (5/10) and loss (4/10) (never relocated) rates were reported for beaver translocated in the James Bay area of Quebec, Canada (Courcelles and Nault 1983). Translocated animals undoubtedly have a higher susceptibility to predation for many reasons including unfamiliarity with the surrounding habitat, reduced fitness due to trapping stress, and possible exposure to more numerous and greater varieties of predators (Griffith et al. 1989; Stanley-Price 1989). Beaver have many natural predators and do not avoid predation through fighting, preferring instead to use water as an escape medium (as reviewed in Smith et al. 1994). Without ponds and dens to use for escape, Beaver are vulnerable to predation.

TABLE 3. Kaplan-Meier 180 and 360 day survival estimates, sample sizes, 95% CIs, and SEs for Beavers translocated in Wyoming. Survival estimates were not computed for Beaver < 2 years old since 100% either died or emigrated prior to 180 days.

Age Class	N Total	n Surviving	n Dying	n Unknown	Survival Estimate	95% CI	SE
180 days							
All ages	114	23	34	58	0.493	0.358–0.628	0.068
2.5–3.5 years old	52	13	20	19	0.436	0.271–0.602	0.085
4+ years old	51	10	8	33	0.658	0.449–0.868	0.107
360 days							
All ages	114	13	36	66	0.433	0.268–0.598	0.084
2.5–3.5 years old	52	7	22	23	0.353	0.167–0.538	0.095
4+ years old	51	6	8	37	0.658	0.449–0.868	0.107

[a]animals either emigrated > 5 km or transmitters failed

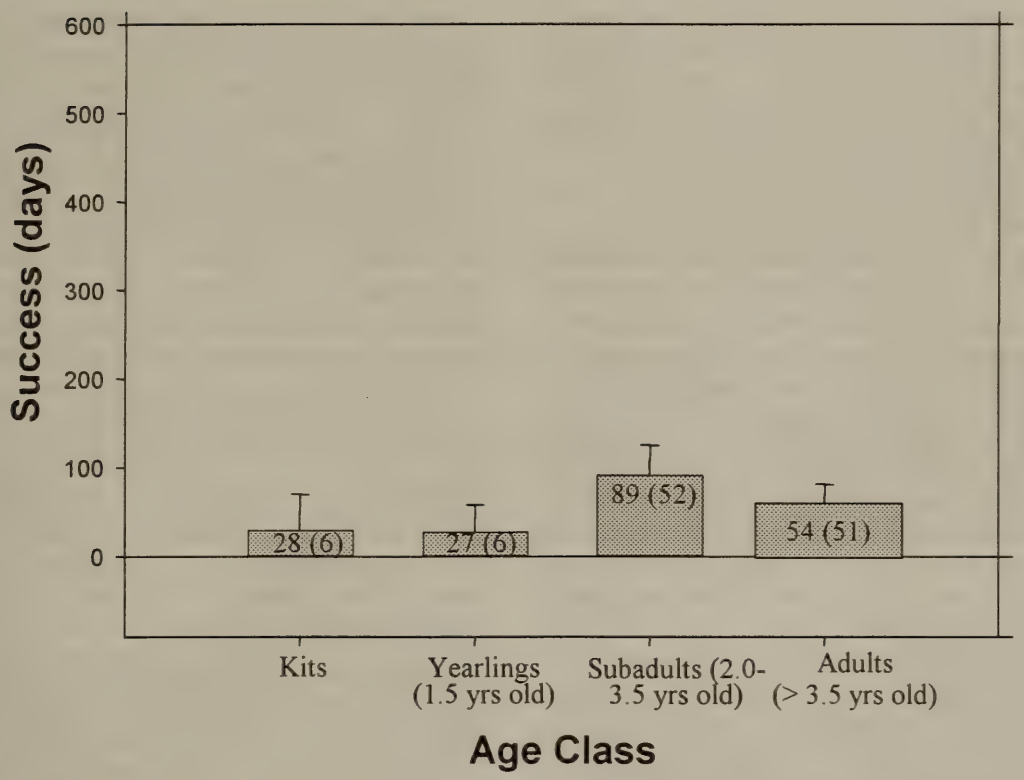

Figure 2. Average survival, in days (n), for four age classes of relocated beavers. Error bars depict 95% CI's.

Naturally dispersing Beaver have been seen in upland areas > 1 km from water sources and have been observed crossing mountain passes (Smith 1980) far from water where they would be extremely vulnerable to predation. Movements across upland areas are undoubtedly successful but we question the frequency of this success in areas like Wyoming where multiple predators occur sympatrically.

Translocated Beaver in North Dakota, Wisconsin, and Maine moved an average of 14.6, 7.4 and 11.2 stream km, respectively, although the longest movement was 238 km (Hibbard 1958; Knudsen and Hale 1965; Hill 1982) and naturally dispersing Beaver in Idaho and Quebec moved an average 8.5 and 18 km (Leege 1968; Courcelles and Nault 1983). While movements greater than 3 km are common for Beaver, exposure rates certainly increase during long movements through non-ponded habitat. Our animals may have been attempting to return to trapping locations, which were greater than 160 km away. Since our goal was to establish Beavers in uncolonized areas, predation risk was unavoidable and high predation and emigration losses should be considered when planning releases.

Wildlife managers in Europe have made several attempts to transplant Beaver (*C. fiber*) with varied success (Zurowski and Kasperczyk 1988; Hartman 1994; Nolet and Baveco 1996). Initially, mortality and emigration rates were high (14-36% and 23%, respectively) and were greatest in juvenile and yearling animals. Mortality rates declined with the establishment of dens and dams and populations became well established over time. However, transplanting in Europe usually occurs in major river systems where flooding of the dens is the primary disruptive event and predator populations are not as large (Nolet and Baveco 1996). In Wyoming, predator communities are well developed and are thought to be increasing (McKinstry and Anderson in review). Additionally, Beaver introduced in large rivers (> 2.83 m/sec) have greater aquatic escape cover than Beaver released in the small (< 0.283 m/sec) streams where we were working.

The value of riparian areas for wildlife has been emphasized by many authors (as reviewed by Naiman et al. 1988), but predator-prey relationships in riparian areas and how they relate to habitat quality and availability are not well understood (Smith et al. 1994). During drought periods animals may concentrate in riparian areas along with their respective predators. These predators, while normally dependent upon another prey species, may find Beaver easy prey. Many wildlife species use riparian areas more frequently during fall due to increased forage and water in the riparian areas. Predators may also concentrate in these areas to take advantage of higher prey densities, greater water availability, and lowered temperatures. Our releases were primarily (71%) done during the fall (15 August–10 October) to take advantage of the Beaver's natural tendency to begin construction of dams and lodges in the fall (Vore 1993). We did spring releases to establish Beaver in

ephemeral streams that were normally dry by mid August and to supplement one or two Beaver that had become established the year before. Relocations in the spring may have lower predation risks, although we did not see this relationship in our analyses.

Several biologists suggested that we create small ponds at release sites to provide temporary refuge for released Beaver. In the two instances (Bear Gulch and Spring Creek; see Table 2 for specific numbers released) where we released Beaver into remnant ponds they emigrated from those areas within 10 days and constructed their own dams and lodges elsewhere in the drainage, although the remnant ponds may have provided them with initial protection from predators and helped to acclimate them to the area. Furthermore, creating small ponds is cost prohibitive and unlikely to be used in future transplants, therefore we did not consider this as a legitimate tool in our transplants.

Our goal was to establish Beaver at release sites, therefore we continued to release Beaver until dams and lodges were constructed. On average we released 17 Beaver/site before they constructed a dam and lodge and successfully reproduced. In 11 instances a single Beaver created a pond with a lodge and we transplanted additional animals in the hope that they would pair-up. We expected that many Beaver would emigrate from our release sites in efforts to return home, search for mates, or look for more suitable habitat. High predation and emigration rates for introduced Beaver should be expected (Griffith et al. 1989) and planned for in any Beaver translocation project.

We found no significant predictors of success or survival in our analyses. The 2–2.5 year-old Beavers had greater average success (Figure 2) and other researchers (Vore 1993; P. Jensen, Pennsylvania State University, personal communication) have suggested that this age class may be more suitable for recolonizing new areas since they are predisposed to emigrating, establishing new territories, constructing dams and lodges, and attracting mates. Our results are inconclusive but we recommend translocating Beavers > 2 years old since mortality and emigration of our younger animals totaled 100% within six months.

Our results also call attention to programs where only one or two Beaver are relocated to either unoccupied habitat, usually under the pretext of improving habitat, or to areas with existing Beaver populations. These activities are common in the western US and are usually carried out by district biologists or conservation officers to remove nuisance Beaver without using lethal techniques. We suggest that unless managers are committed to successfully introducing Beaver through planned introductions, monitoring, and follow-up releases their time and money may be better spent on other duties.

In summary, we found that Beaver could be used to create natural wetlands and improve riparian habitat in 13/14 streams where we relocated them. Mortality (30%) and emigration (51%) totaled 81% within the first 6 months of release and we needed to relocate an average of 17 Beaver/site to get a pair to establish and reproduce. Additional releases were also needed to augment single animals that had become established. Wildlife response to our created habitats was immediate (McKinstry et al. 2001) and landmanagers found that the habitats were valuable to both wildlife and livestock. We caution that releases should only be used in drainages where conflicts with irrigation or road crossing structures are minimal and preferably where the drainage is controlled by a few landowners to simplify evaluation and management.

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Songbird Community Composition Versus Forest Rotation Age in Saskatchewan Boreal Mixedwood Forest

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Songbird communities were characterised using unlimited-distance point counts in four age-classes of boreal mixedwood forest in central Saskatchewan in 1991. Forest age-classes surveyed were: mature stands (50-60 years old), rotation age stands (80-90 years), old stands (100-110 years), and very old stands (>140 years). Ten species (Winter Wren, *Troglodytes troglodytes*; Golden-crowned Kinglet, *Regulus satrapa*; Ruby-crowned Kinglet, *R. calendula*; Swainson's Thrush, *Catharus ustulatus*; Tennessee Warbler, *Vermivora peregrina*; Blackburnian Warbler, *Dendroica fusca*; Magnolia Warbler, *D. magnolia*; Bay-breasted Warbler, *D. castanea*; Rose-breasted Grosbeak, *Pheucticus ludovicianus* and Evening Grosbeak, *Coccothraustes vespertinus*, were significantly more abundant in forest that was older than rotation age. Four of these species (Winter Wren, Tennessee, Magnolia and Bay-breasted warblers), reached their highest densities only in the oldest (>140) age class. Two species (Red-eyed Vireo, *Vireo olivaceus*, and Ovenbird, *Seiurus aurocapillus*) were significantly more abundant in forest that was rotation age or younger. In boreal mixedwood forest, habitat-selection patterns of songbirds suggest that many species, not also occurring in rotation-aged or younger stands, may require substantially older forest in order to persist.

Key Words: songbirds, boreal, mixedwood forest, rotation age.

Boreal forest is one of the largest terrestrial ecosystems on the planet (Shugart et al. 1992; Apps et al. 1995). It comprises 20% of the world's forest and is the largest terrestrial ecozone in Canada, covering more than one-third of the country (Rowe 1972; Shugart et al. 1992). The southern part of this forest, the boreal mixedwood, supports the best tree growth (Rowe 1972) and is under the most pressure from human activities. In the three Prairie Provinces, more than 90% of the boreal mixedwood forest has been leased for harvesting under Forest Management Agreements (Cummings et al. 1994; Pratt and Urqhart 1994; Alberta Environmental Protection 1998*). In Saskatchewan, over 80% of trees harvested come from mixedwood forest, predominantly White Spruce (*Picea glauca*) and Trembling Aspen (*Populus tremuloides*), especially from the older age classes (Spencer 1993). This type and age of forest accounts for, at most, 10% of the commercial forest (Kabzems et al. 1986), yet it is also the most biologically diverse habitat in the region (Welsh 1981; Harris et al. 1984; Acton et al. 1998). Thus, the biologically richest stands are being harvested in a proportion far exceeding their abundance (Erskine 1977).

Canada is required under the Biodiversity Convention to ensure the ecological sustainability of all its ecosystems (Biodiversity Science Assessment Team 1994*), and the global market is demanding that suppliers of forest products demonstrate the environmental sustainability of their harvesting practices (Canada 1995*). As boreal mixedwood forest comes under increasing pressure from harvesting, foresters will be expected to maintain biodiversity (CCFM 1992*; Freedman et al. 1994; Middleton 1994*) but currently lack the information required to do so. When a previously little-exploited segment of the forest resource, such as old-growth mixedwood boreal stands, becomes the focus of intensified harvesting, the assessment of impacts on biodiversity becomes an urgent priority.

Our study was designed to address the question: "Are there elements of the biological community of old-growth boreal mixedwood forest whose survival may be threatened by harvesting?". In his 1977 study on boreal songbirds, Erskine suggested that the "...mature stage of the most fertile needle-leafed community" is biologically the most diverse community in the boreal forest and "...deserves more attention from environmental impact studies than they have received". Specifically, we used songbirds as focal organisms, expecting that they might be useful indicators of impacts on other organisms, and perhaps of biodiversity as a whole (Freedman et al. 1994). Songbirds are primarily insectivorous, feeding sufficiently close to the top of their food-chains to be potentially useful indicators of impacts on a wide range of organisms (Diamond and Filion 1987; Furness and Greenwood 1993).

We chose a range of stand ages around the proposed rotation age (80–90 years), to assess whether, in the extreme case of all stands older than rotation age being eliminated from the landscape, an impact

TABLE 1. Species which occurred significantly more or less frequently in a given forest age (Anova with Tukey's test).

Species	F	DF	P	Significant Age
Winter Wren	87.1	3	***	140 >
Tennessee Warbler	3.0	3	*	140 >
Magnolia Warbler	4.8	3	**	140 >
Bay-breasted Warbler	6.9	3	***	140 >
Ruby-crowned Kinglet	6.1	3	**	100 >
Blackburnian Warbler	7.1	3	***	100 >
Black-throated Green Warbler	4.3	3	**	100 >
Rose-breasted Grosbeak	4.5	3	**	100 >
Swainson's Thrush	7.2	3	***	50 <
Red-eyed Vireo	4.3	3	**	80 >
Ovenbird	12.6	3	***	140 <

*<0.05, **<0.01, ***<0.001

on the bird community could be expected. Our youngest age-class was 30 years younger than rotation age. We did not study stands younger than this, because other studies have shown the songbird community to be very different between young (<30) and old (>80) forest (Titterington et al. 1979; Schiek et al. 1995; Hobson and Bayne 1999). In addition, intensified management will lead to an increased abundance of younger age-classes at the expense of those older than rotation age (Spencer 1993; Weyerhauser Canada 1998*).

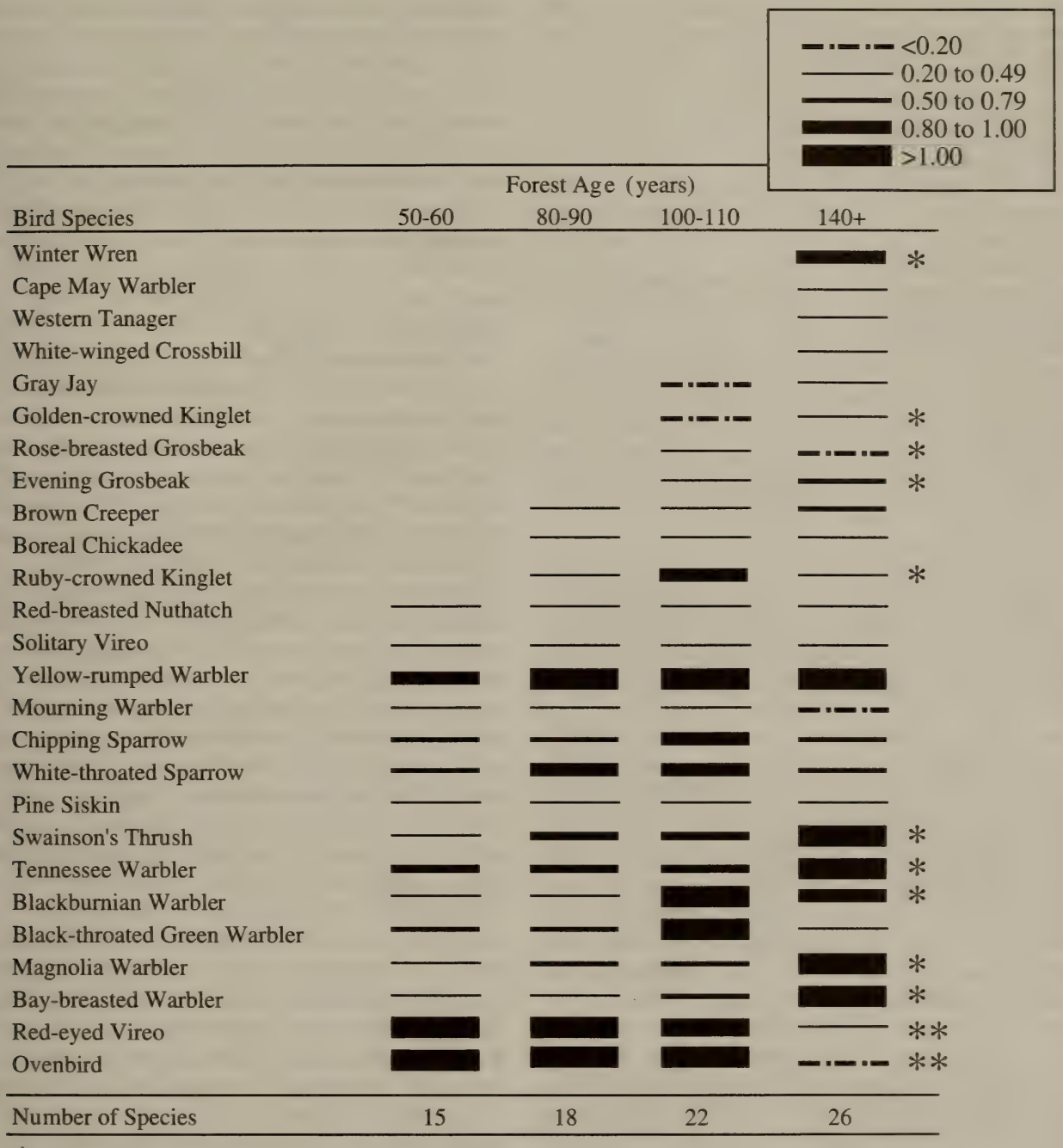
It is already known that a reduction in stand age may have negative effects on some bird species (Titterington et al. 1979; Welsh 1981; Farr 1993; Schiek et al. 1995), but effects on particular species in spruce-dominated mixedwood forest have not previously been addressed. Previous studies have shown that old mixedwood forests have a rich assemblage of bird species (Erskine 1977; Kirk et al. 1996). Many of these species do not occur in younger forest, or in hardwood dominated forest, or do so only at low densities (Stelfox 1995; Hobson and Bayne 1999).

Methods

This study was carried out in summer 1991 in and around Prince Albert National Park, Saskatchewan (53° 35'N 106° 00'W) (see Bayne and Hobson 1997), in boreal mixedwood forest (Kabzems et al. 1986; Acton et al. 1998). Ten study sites were established in forest of four different ages: three stands >140 years old, three 100–110 years old, two 80–90 years old and two 50–60 years old, and were aged by coring six of the largest trees on each site. All sites were mixedwood forest and were as similar as field conditions allowed. Sites were pre-selected for similarity using Saskatchewan forest inventory maps, which are based on similarity of tree density and species composition (Kabzems et al 1986). Ground truthing showed stands were similar in species composition and tree density, however, older sites did tend toward greater abundance of conifers (Cumming 1995). The largest and most abundant trees in all stands, were White Spruce and Trembling Aspen. Two other species, White Birch (*Betula papyrifera*) and Balsam Fir (*Abies balsamea*) also occurred (Cumming 1995). The main shrubby species were young Balsam Fir, White Birch, Alder (*Alnus sp.*) and Beaked Hazel (*Corylus cornuta*). Ground cover was mainly composed of several species of moss; Bunchberry (*Cornus canadensis*); Twinflower (*Linnaea borealis*) and Wild Sarsaparilla (*Aralia nudicaulis*).

Birds were counted using the unlimited-distance point count method (Bibby et al. 1992), which is widely used as the method of choice when large areas need to be surveyed rapidly and efficiently (Verner 1985; Farr 1993; Bancroft et al. 1995). The method is a good indicator of relative abundance (Verner and Ritter 1985; Bancroft et al. 1995) and an efficient method for comparing species composition and richness between habitats (Blondel et al. 1981). Point counts were at least 200 m apart and 100 m from a stand edge; these distances minimise the chances of double-counting, and including species from other habitats, respectively. Surveys were conducted between 04:00 and 09:00, by the same observer (EEC), and included all birds seen or heard in 10 minutes. Each site was surveyed twice during the breeding season; early (1–14 June) and late (20 June–4 July). Such spacing of surveys gives a more representative picture of a bird community than either one survey, or two carried out on consecutive days (Hilden 1981; Skirven 1981).

Because sampling effort differed between stands, (five point count stations/site in the oldest category, and three/site in the other three categories), the data were standardised by dividing the maximum number of individuals of each species recorded in a particular age class by the number of point counts. This gives the probability of detection for a particular species in that age of forest. Birds that were flying overhead, or had very large territories, such as raptors, ravens, and woodpeckers were not included in the analysis.



* more abundant in post rotation age sites ($p<0.05$)

** more abundant in sites at or below rotation age ($p<0.05$)

FIGURE 1. Probability of detecting a given species of bird at a point count in the different forest age classes.

Vegetation was measured in 0.04 ha circles (22 metres in diameter), using a modified James and Shugart (1970) method. Two such circles were located near each point count station, one centred on the point count location, with the other located in a random direction 50 metres away. In each plot, the species, diameter (dbh), and height of each tree was recorded. Plants with a dbh greater than 7 cm were considered trees, while those less than 7 cm dbh were classified as shrubs (James and Shugart 1970). Percent shrub cover was estimated for the entire plot, and ground cover was estimated in four randomly located 1m^2 quadrats.

Data were analysed using 1-way Anova (Zar 1996) using the statistical package SPSS. In the case where more than two categories were used, a Tukey's HSD test was applied to find where differences had occurred (Zar 1996). Both bird and vegetation data were analysed using four age classes and by pooling data for two age classes, either post-rotation age or rotation age and younger.

Results

The number of songbird species recorded in each habitat progressively increased with age, from youngest to oldest the numbers of species were; 15,

TABLE 2. Species which are found significantly more often in post-rotation age forest.

Species	F	DF	P
Winter Wren	15.8	1	***
Golden-crowned Kinglet	3.9	1	*
Ruby-crowned Kinglet	5.0	1	*
Swainson's Thrush	5.3	1	*
Tennessee Warbler	4.1	1	*
Magnolia Warbler	6.1	1	*
Blackburnian Warbler	8.7	1	***
Bay-breasted Warbler	5.9	1	*
Rose-breasted Grosbeak	4.7	1	*
Evening Grosbeak	9.6	1	**
Red-eyed Vireo†	6.8	1	**
Ovenbird†	7.1	1	**

*<0.05, **<0.01, ***<0.001

†Ovenbird and Red-eyed Vireo were found significantly more often in forest of rotation age and younger.

18, 22 and 26 (Figure 1). Eleven species were not detected in the youngest (50–60 years) forest sampled, but no species detected in the youngest forest did not also occur in the oldest (Figure 1).

A 1-way Anova with Tukey's test found that Winter Wren, Tennessee, Magnolia, and Bay-breasted warblers were significantly more abundant in the >140 year old forest (Table 1). Ruby-crowned Kinglet, Rose-breasted Grosbeak, Blackburnian and Black-throated Green warblers (*Dendroica virens*) were most abundant in the 100–110 year old forest while Red-eyed Vireos were most abundant in the 80–90 year old forest. Swainson's Thrushes were least abundant in the 50–60 year old forest, and Ovenbirds were least abundant in the >140 year old forest (Table 1). Pooling the data into pre and post-rotation age showed ten species to be significantly more abundant in post-rotation aged forest (Table 2). Only Ovenbird and Red-eyed Vireo were more abundant in forest of rotation age and younger (Table 2).

The percent of coniferous trees relative to deciduous trees increased with increasing forest age (Table 3). The average height of the forest was not significantly different between the three oldest ages, but the average tree height of the 50–60 year old forest was significantly shorter than the other three (Table 3). The amount of shrub cover and moss cover was significantly higher in the oldest forest, while the amount of litter was significantly higher in the youngest forest (Table 3). The average height of the combined post-rotation age forest (20.4 ± 7.0 m) was significantly taller than the rotation age and younger forest (15.8 ± 3.9 m) ($F = 30.0$, $DF = 1$, $P < 0.001$).

Discussion

All bird species found in the youngest stands also occurred in older forest; however, the reverse was not true. Species were added to the forest with increasing age, and species richness increased with stand age. We sampled more old than young stands, therefore, with increased sample effort some of the missing species may indeed be detected in younger forest. However, our data indicate a definite trend for higher species richness in forest that is older than rotation age and for many species there is also a trend for greater abundance in forest older than rotation age. This may be caused by old forest having higher habitat heterogeneity than young forest, which is thought to contribute to its increased species richness (Meslow et al. 1981; Hunter 1990). This increased heterogeneity has a variety of causes, including windthrow gaps, and tree disease and death, which allows for infilling with various ages and species of trees (Erskine 1977; Hunter 1990).

Studies in Maine, Ontario, and Alberta found Ruby and Golden-crowned kinglets, Winter Wrens, crossbills (*Loxia* spp.), Cape May, Blackburnian, and Bay-breasted warblers were more abundant in mature to old forest and present at either much lower densities, or absent, in younger stands (Titterington et al. 1979; Welsh 1981; Schieck et al. 1995). A small sample size was the most likely reason we did not find Cape May Warbler, Western Tanager (*Piranga ludoviciana*) and White-winged Crossbill (*Loxia leucoptera*) significantly correlated with post-rotation aged forest. However, as they were observed only in the oldest forest sampled, this suggests a

TABLE 3. Percent of coniferous and deciduous tree cover and average height at different ages, and percent of shrub and ground cover at different ages. Percentages are mean ± 1 standard deviation.

				Tall Shrub	Ground Cover			
Age	% Conifer	% Decid.	Height (m)	% Cover	% Moss	% Herb	% Litter	% Grass
140+	80	20	20.1 ± 7.5	41.7 ± 24.6*	53.0 ± 28.3*	4.3 ± 3.5	42.8 ± 27.2	0
100-110	65	35	21.1 ± 6.1	28.8 ± 22.3	9.4 ± 17.4	22.5 ± 16.5	65.6 ± 20.9	2.5 ± 7.1
80-90	48	52	18.3 ± 4.3	22.5 ± 38.6	2.5 ± 5.0	25.0 ± 28.9	70.0 ± 29.4	2.5 ± 5.0
50-60	49	51	13.9 ± 2.0*	2.5 ± 3.9	3.1 ± 2.4	4.4 ± 2.3	92.5 ± 12.9*	0

*Indicates means that are significantly different at P<0.05;1-way Anova;Tukey's HSD.

trend for these species to use mature to old forest, especially as they have been found to be significantly associated with older forest in other studies (Farr 1993; Benkman, 1993).

Some species did not show a significant difference in their habitat preference and occurred at similar densities in all ages tested. Species such as, Solitary Vireo (*Vireo solitarius*); Yellow-rumped Warbler (*Dendroica coronata*); Chipping Sparrow (*Spizella passerina*) and Pine Siskin (*Carduelis pinus*), have been found to be associated with coniferous forest, including Jack Pine (*Pinus banksiana*), rather than forest age per se. (Kirk et al. 1996); and species such as White-throated Sparrow (*Zonotrichia albicolliss*), are widely distributed across a great many forest types and ages (Kirk et al. 1996; Hobson and Bayne 1999).

Many of the 26 species sampled showed some degree of dependence on forest as old as, or older than, the rotation age of 80–90 years. Eight species (30% of the total community) occurred exclusively in stands substantially older than rotation age, and three more occurred only in these stands or those of rotation age; thus 42% of the species in this community showed a marked degree of dependence on mature or old stands. In addition, five other species (Swainson's Thrush, Tennessee, Blackburnian, Magnolia, and Bay-breasted warblers), that occurred in all age classes, were significantly more abundant in the post-rotation age forest. We conclude that 62% of these species (16/26) are likely to suffer some reduction in population density if stands older than rotation age are altogether lost from the landscape.

Several of the species which occurred in younger stands did so at low abundances; for these species, young stands could potentially represent population sinks (van Horne 1983; Pulliam 1988), in which populations can only be maintained by immigration. Many of the species that were age-sensitive also appear to be area-sensitive (Hobson and Bayne 2000). As these species appear to show sensitivity to age and fragmentation, we suggest that there is a need for further research on the habitat requirements and reproductive biology of these species. This is especially true as many of these species may also be facing habitat loss in the southern fringe of the boreal mixedwood forest (Cumming et al. 2001; Hobson et al. *in press*).

We conclude that managed boreal mixedwood forest should maintain some stands of at least 120 years or older if the communities characteristic of the whole forest ecosystem are to be sustained. Natural disturbance patterns could be used to guide the proportion of the landscape to be retained in this age-class. The question of the most appropriate size and configuration of such old-growth stands, in relation to conservation of songbirds, was not addressed by our study, but we draw attention to abundant evidence that reduction in forest age, and fragmentation of forest patches (a process that has accelerated in central Saskatchewan in recent years, Fitzsimmons et al. 1997*) can have serious implications for the sustainability of songbird populations (Schieck et al. 1995; Villard et al 1995; Cumming et al. 2001)

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Status of Redside Dace, *Clinostomus elongatus*, in the Lynde and Pringle Creek Watersheds of Lake Ontario

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Andersen, Jeff J. 2002. Status of Redside Dace, *Clinostomus elongatus,* in the Lynde and Pringle creek watersheds of Lake Ontario. Canadian Field-Naturalist 116(1): 76–80.

Populations of the Redside Dace, *Clinostomus elongatus*, are declining throughout most of their Ontario range. Since 1959, Redside Dace have been found at 20 sampling sites in Lynde and Pringle creeks within the Town of Whitby, Ontario. These collection sites were reassessed in 1999 and 2000 to investigate the status of the Redside Dace within these systems. A total of 20 Redside Dace were captured at four of the 20 sites. Populations are now either severely limited or absent from Pringle Creek and are now confined to upstream areas in Lynde Creek. Redside Dace were confined to 2nd and 3rd order coolwater streams with variable substrata, and these habitats displayed a 100% canopy closure by grass species. Potential Redside Dace habitats are identified within the watershed to provide general guidelines for future land development.

Key Words: Redside Dace, *Clinostomus elongatus*, fish, minnows, threatened species, special concern, vulnerable species.

The Redside Dace has a discontinuous global distribution and is found only in North America. In the western portion of its range, it occurs in the upper Mississippi and Lake Michigan drainages, and, in the eastern portion, in the Lake Erie, Lake Huron, Lake Ontario and upper Susquehanna River drainages. Page and Burr (1991) describe the Redside Dace as locally common in the eastern part of its range although it is declining in many areas. The Redside Dace is localized and rare in the western part of its range. Collection records for Redside Dace in Ontario indicate "the general distribution included tributaries of Lake Ontario from Lynde Creek in the east to Spencer Creek on the west, and north to the headwaters of these systems" and "in the Lake Simcoe drainage limited to Kettleby Creek" (Parker et al. 1988). They are also known to occur in the Saugeen River watershed, Gully Creek and Two Tree River in the Lake Huron Drainage, and from Irvine Creek in the Lake Erie Drainage.

The Redside Dace, *Clinostomus elongatus*, was classified as Vulnerable in Canada by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) in 1987. In 2000, COSEWIC changed the "Vulnerable" classification to Special Concern (COSEWIC 2000). Studies are currently underway to reassess the status of the Redside Dace on behalf of COSEWIC (E. Holm, Royal Ontario Museum, personal communications January 1999 to January 2000). The Ontario counterpart of COSEWIC, the Committee on the Status of Species at Risk in Ontario (COSSARO) designated the Redside Dace as Threatened in Ontario in May 2000 (COSSARO 2000).

Redside Dace prefer cool, clear, flowing waters with a substrate composed of gravel or stone and are reported to be quite sensitive to turbidity (Scott and Crossman 1973; Trautman 1981). Redside Dace differ from other members of the family Cyprinidae in that approximately 77% of their diet consists of insects. Daniels and Wisniewski (1994) suggest a dominance for flying insects made up mainly of danceflies, caddisflies and midges. The Redside Dace possesses large eyes and has a very large mouth which allows it to catch these in flight by leaping out of the water.

Lynde and Pringle creeks, located in the Township of Whitby, Region of Durham, Ontario, centered at 43° 56′ 30″ W, 78° 59′ 10″ N (Figure 1), are the only creeks reported to support Redside Dace within the Central Lake Ontario Conservation Authority (CLOCA) watershed (CLOCA 1996–2000*).

Redside Dace habitat was described by Parker et al. (1988) as pools and slow moving sections of relatively small headwater streams which have a pool riffle habitat. Stream sections with overhanging bushes and herbaceous plants to provide some cover were found to be particularly suitable. Bottom substrates were usually composed of boulders, rocks gravel or sand, often with a shallow surface covering of detritus and silt. Streams were clear and colourless in conjunction with hard substrates and clear to brown tinged streams with organic substrates. This species prefers clear water and is quite sensitive to turbidity. Novinger and Coon (1998) describe a micro-habitat preference for mid-water positions in the deepest parts of pools under overhanging vegetation.

The status of the Redside Dace in Lynde and Pringle creeks had not been assessed since 1985. Due to the stresses of increased development within the Lynde and Pringle creek watersheds and the sensitivity of Redside Dace to increased turbidity, an

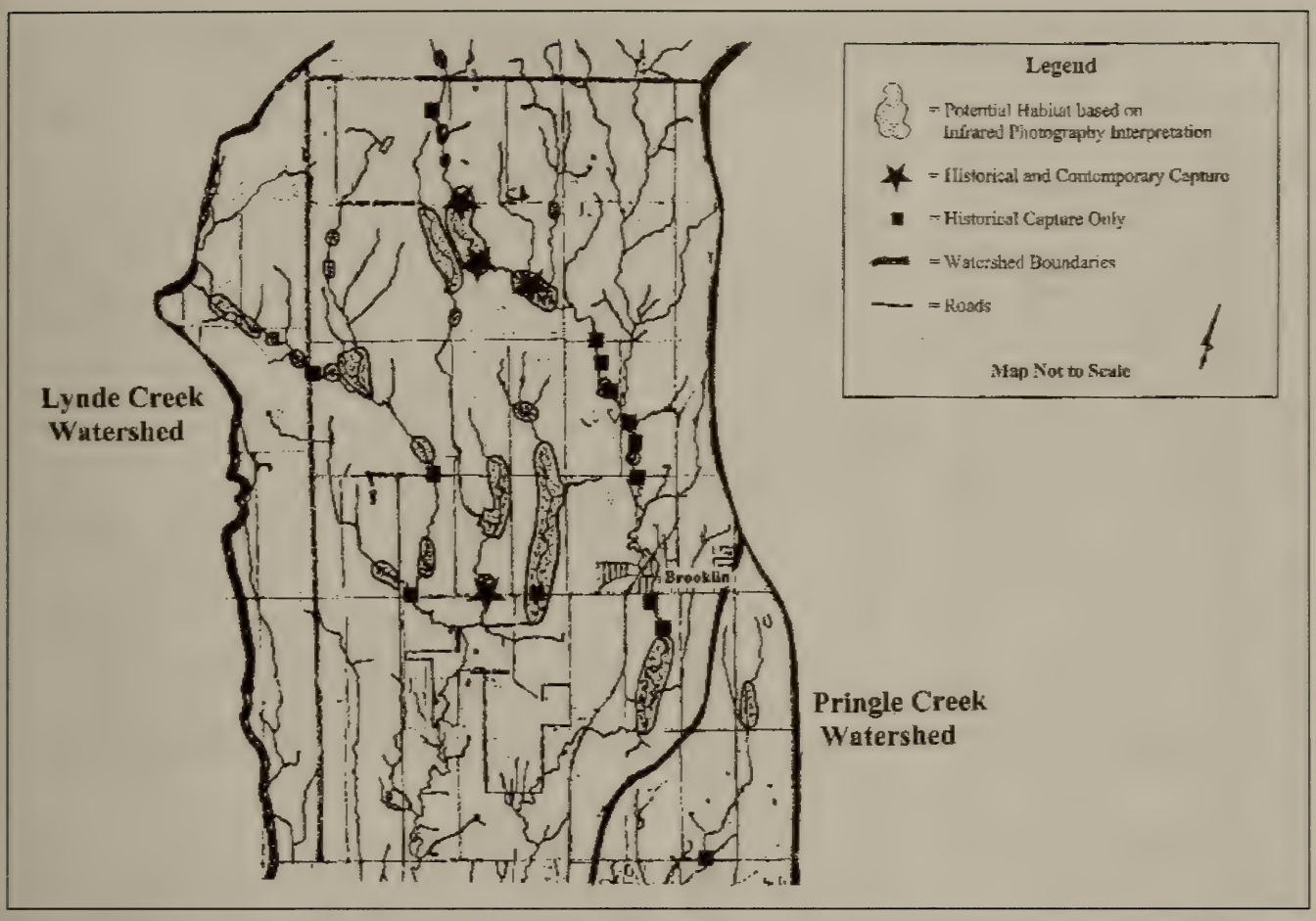

FIGURE 1. Historical (■) and contemporary (★) Redside Dace, *Clinostomus elongatus*, collection sites and potential habitat on Lynde and Pringle creeks.

impact on the Redside Dace population would appear inevitable. The purpose of this study would be an attempt to summarize historical capture data, resurvey all known capture sites, identify the current status and range of known Redside Dace habitat and predict potential Redside Dace habitat within the Lynde and Pringle creek watersheds.

Methods

Historical Capture Mapping

All historic collection sites from 1959 to 1999 were taken from the CLOCA Fisheries Database and mapped on a 1:10000 Ontario Base Map (Figure 1). Exact locations were difficult to assess due to location reporting in previous studies which were given in general or relative terms. Survey locations were, therefore, derived from a combination of the above information, landmarks denoted in field records as well as conversations with individuals who conducted the studies (E. Holm, personal communication 1999).

Collection

Sample collections for the historical studies on the Lynde and Pringle were conducted with seine nets and dip nets only (Archives of Ontario 1959* and Tumey 1984*) or a combination of seine and electrofishing (Holm and Crossman 1986*), and were qualitative in nature. For the current study, qualitative fish samples were obtained using the single-pass electrofishing method described in Stanfield et al. (1997). Sampling areas coincided with areas of historic Redside Dace occurrence. This method was effective and least harmful to the fish compared to netting methods due to the speed of the sample and the relatively short electrical field exposure time. The length of steam electrofished ranged from 18 to 123 metres and averaged 49 metres. The electrofisher was set at 45 Hertz at 4 seconds with an output of 300 Volts.

Field collections were conducted July and September 1999 and August and October 2000. All species captured were noted and Redside Dace capture locations were determined using UTM coordinates. All species were identified in the field and a sample of Redside Dace specimens from each capture site were sent to the Royal Ontario Museum for verification.

Habitat Mapping

Potential habitat was identified using Ontario Ministry of Natural Resources rectified colour infrared photographs (Ontario Ministry of Natural Resources 1997). Areas were identified that were 2nd, 3rd and 4th order streams on the Lynde and

Pringle creeks. These systems were within agricultural areas with riparian vegetation made up of mainly grass species.

Results

Historical Data Summary

Historically, Redside Dace have been noted in both Lynde and Pringle creeks located within the Town of Whitby (Figure 1). In four surveys on the Lynde and Pringle creeks the capture of the Redside Dace was reported (see site codes in Table 1 and Figure 1). The first survey was conducted in 1959 by the Ontario Department of Planning and Development, wherein five sites on the Lynde Creek and one site on Pringle Creek produced Redside Dace (see Table 1 site codes preceded by "OPD"). A second survey conducted by Tumey in 1983 noted 10 Redside Dace capture locations on the Lynde (see Table 1 site codes preceded by "CLOCA"). The third survey produced one confirmed (Royal Ontario Museum) Lynde Creek specimen taken by Niblett Environmental Associates in 1997 (see Table 1 site code preceded by "NEA"). The fourth, and most recent study conducted by EcoTec in 1999 noted Redside Dace within the Lynde Creek at two sites along the Highway #7 corridor (see Table 1, site codes preceded by "EcoTec"). Holm and Crossman (1985) resurveyed three of the 1959 survey locations, and one new site, but no Redside Dace were found. They suggested that in Lynde and Pringle creeks; (1) there has been a significant decline of *C. elongatus* in the waters sampled, (2) *C. elongatus* has been seriously limited or extirpated from Pringle Creek, (3) either the number of individuals, or the area of the watershed occupied by the species, has declined in Lynde Creek, and (4) there appears to be healthy populations in other watercourses. The recommendations from this survey concluded; "Urbanization definitely seems to reduce the area of any watershed which remains suitable to *C. elongatus*. It is recommended for streams with known populations of *C. elongatus* that wherever possible, the stream-side vegetation be maintained and instream cover and obstructions such as logs not be removed (i.e., channelization be avoided), this will maintain the pool-riffle habitat and supply a source of terrestrial insects — an important food source for the redside dace".

According to these conclusions and recommendations, the decline or extirpation of Redside Dace in the Lynde and Pringle creek systems appears imminent. Lynde and Pringle creeks have been subject to many stresses over the years including urban development and subsequent channelizations and stormsewer outfalls. Many other groups have surveyed Lynde and Pringle creeks in the vicinity of many known Redside Dace occurrences (CLOCA 1996–2000) and have not captured any specimens since 1996, with the exception of the Niblett Environmental Associates survey (1997). Redside Dace occurrences had not been previously reported at the two sites studied by EcoTec (1999*) even though the sites had been surveyed prior to 1999.

Contemporary Study Results

A total of 20 Redside Dace were collected at four of the 20 historical collection sites (Table 1) and specimens were verified as *C. elongatus* (ROM Accession #6844). The average total length was 80.5 mm (ranging between 48–101 mm) and the average weight was 4.94g (ranging between 2–10.1 g) for all samples. At the sites where Redside Dace were captured, the following consistent characteristics of the aquatic and riparian habitat were noted; 2nd or 3rd order streams, a relatively steep gradient (1.0–1.59%), riffle pool sequences, cool water (summer temperatures between 16.0°C and 24.0°C), a streamside vegetation made up of grasses providing 100% canopy cover, a lack of instream woody debris, a surrounding land use of reclaimed agricultural or recreational (golf course) and variable substrata including; silt, sand, cobble and rock.

Discussion

Existing and Potential Habitat

The four capture sites contained similar habitat. It was determined that this habitat type, with some exceptions (see below), could be identified in a desktop exercise using rectified colour infrared aerial photography (Ontario Ministry of Natural Resources 1997). Reclaimed agricultural areas that were not excessively forested and had riparian vegetation consisting of mainly grass species were denoted as potential habitats (Figure 1). The findings derived from this exercise do not preclude other areas and habitat types from being Redside Dace terrestrial habitat, rather, they represent areas within Lynde and Pringle creeks that contain a habitat type that has been proven to support Redside Dace. However, there are limitations in the "desktop" method of habitat typing: some areas of identified potential habitat are either within an ephemeral or intermittent watercourse, or do not have sufficient flows to support Redside Dace (Parker et al. 1988); other areas may have either thermal characteristics outside Redside Dace tolerance range, or substrates and riffle/pool characteristics not normally associated with Redside Dace habitat (Scott and Crossman 1973). Furthermore, fragmented areas of potential habitat are evident within some tributaries and it is unknown if these pockets provide enough habitat to be considered "potential". For the purpose of this study, these areas are included as the potential for Redside Dace habitat is evident. It would appear that Redside Dace populations are becoming more restricted within Lynde Creek and are either severely limited

TABLE 1. Fish species captured during Redside Dace sampling conducted in Lynde and Pringle creeks in 1999 and 2000.

	Site Code																		
Species	OPD CB1a2 (Pringle)	OPD CA2a4 (Lynde)	NEA 01 (Lynde)	OPD CA2a6 (Lynde)	CLOCA 44 (Lynde)	CLOCA 47 (Lynde)	CLOCA 55 & OPDCA1a5 (Lynde)	EcoTec 19 (Lynde)	EcoTec 20 (Lynde)	OPD CA1a4 (Lynde)	OPDCA1a3 (Lynde)	CLOCA 81 (Lynde)	CLOCA 74 (Lynde)	CLOCA 58 (Lynde)	CLOCA 59 (Lynde)	CLOCA 61 (Lynde)	CLOCA 62 (Lynde)	CLOCA 68 (Lynde)	**Totals**
Salmonidae																			
Oncorhynchus mykiss			18	4	1	1	4			4				4	16	1	2		55
Salvelinus fontinalis				1						1					4		1		7
Catostomidae																			
Catostomus commersoni		9	10	17	22	9	4	7	8				7				2		95
Cyprinidae																			
Phoxinus eos	1				7		1		20		3	1						1	34
Clinostomus elongatus								13			3		1					3	20
Luxilus cornutus				1	3	1													5
Pimephales promelas	11						4	5	20		1	3			2			2	48
Rhinicthys atratulus	128	31	64	58	66	23	81	27	31	66	31	32	44	9	24	22	25	29	791
Rhinicthys cataractae		4	8		14	2	2			2				1			21		54
Semotilus atromaculatus	17	85	63	60	46	24	37	82	52	4	28	29	58	8	5	1		60	659
Gasterosteidae																			
Culaea inconstans	3					1	2												6
Centrarchidae																			
Micropterus salmoides		1																	1
Lepomis gibbosus	2	1							3		3		11						20
Percidae																			
Etheostoma caeruleum				3	10	1									2				16
Etheostoma nigrum		10	14	22	98	20	8		2					3					177
Cottidae																			
Cottus bairdi		4	16	1	1					1				25	22	6	1		77
Total Number of Specimens	162	145	193	167	268	82	143	134	136	78	69	65	121	50	75	30	52	95	2065
Total Number of Taxa	6	8	7	9	10	9	9	5	7	6	6	4	5	6	7	4	5	5	16

or absent within Pringle Creek. Although the range of occupation of the Redside Dace within Lynde Creek has been reduced, those populations residing in suitable habitat appear to be healthy based on specimen condition and numbers captured (Table 1). According to historical field notes, the land use surrounding each capture site has remained relatively unchanged since first being sampled. Those sites that have seen a significant land use change (i.e., from forested to agricultural or vice-versa) since the time of the first sample event did not contain Redside Dace. It would appear that any changes to the above noted habitat characteristics would result in a absence of Redside Dace capture. One example of this was discovered north of the Hamlet of Brooklin wherein a capture site described as agricultural in 1959 has been reclaimed by an Eastern White Cedar forest by 1999 and did not display Redside Dace capture. Development in and around the Hamlet of Brooklin has limited the range of the Redside Dace within this area, possibly due to increased sediment loading and turbidity, riparian vegetation removal and temperature changes.

Population Management Considerations

Populations of Redside Dace throughout their Ontario Range could be subject to a similar exercise as reported here to determine the Provincial population status in a consistent manner. Redside Dace populations would benefit throughout their range if the strictest levels of sediment and turbidity controls are utilized during residential and agricultural devel-

opment. Further areas of study should give consideration to population estimation, measurements of; physical habitat, thermal condition nutrient status, dissolved oxygen and turbidity, and the relationship of migration barriers to Redside Dace populations.

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Aquatic Leaves and Regeneration of Last Year's Straw in the Arctic Grass, *Arctophila fulva*

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Aquatic leaves are reported and described for the grass *Arctophila fulva*. Re-growth from apparently dead, previous season's straw that had over wintered in the Arctic, is reported. Observations on transplanted material and field observations documented that new shoots grew from the apex, and nodes of previous season's stems. Strong underground rhizomes, and roots developed resulting in propagules able to develop into new plants. The previous season's straw that regenerates is probably detached by animals mid-season, before food reserves in the stems are withdrawn to the rhizomes and roots. Such re-generation of detached straw that has over wintered has not been reported previously for any other grass species.

Key Words: Poaceae, *Arctophila fulva*, aquatic leaves, vegetative proliferation, Banks Island.

The grass *Arctophila fulva* (Trin.) Rupr. has a low Arctic circumpolar distribution (Porsild 1957; Tzvelev 1976; Aiken et al. 1996, 2000*). In North America, it occurs in Alaska, the Yukon, the Northwest Territories, Nunavut, Ontario, Quebec, and Labrador. The northern-most record for the species in the Western Canadian Arctic Archipelago is from Prince Patrick Island, 76°12′N, 119°25′W, (Canadian National Herbarium (CAN) 220464). Plants grow in shallow, standing water or in wet marshy areas where they often form more or less pure stands generally 20–50 (and occasionally up to 100) cm high. The species is easily recognized because, unlike any other grasses or sedges that occur in the same areas, the mature plants have leaves that are conspicuously larger towards the top of the plant than those at the base (Aiken et al. 2000*).

The occurrence of aquatic leaves in grasses is so rare that this is not one of the 1087 characters considered for the 9593 taxa in World Grass Species (Clayton 1999*). In Canada, wild rice taxa in the genus *Zizania* L. and Signal Grass *Pleuropogon sabinei* R. Br. were the only grasses found to develop aquatic leaves in the survey done for Watson et al. (1986).

Porsild (1957) noted that *A. fulva* "near its northern limit is often sterile, propagating itself vegetatively". He gave no information on the nature of the proliferation and did not describe the propagules. Vegetative proliferation by bulbils, formed in place of flowers, occurs in the North American arctic grasses *Poa pratensis* (L.) subsp. *alpigena* (Fr. ex Blytt) Hiitonen and *Festuca viviparoidea* Krajina ex Pavlick s.l. (Aiken et al. 2000*). Vegetative proliferation by fragmentation of stolons and vertical shoots, as a result of goose foraging, appears to be mainly responsible for the spread of *Puccinellia phryganodes* (Trin.) Scribn. and Merr., a grass not known to set seed, and the sedge *Carex subspathacea* Wormsk. that rarely sets seed (Chou et al. 1992; personal communication J. Cayouette 2002).

In these species the establishment of the propagules occurs in the same growing season. Aerial stem fragments can be used as cuttings to produce new plants of Bamboos (sample bought in Ottawa February 2002), but this is not known for any native grasses that occur in Canada, and is unlikely as the stems are annual.

In July 1999, *Arctophila fulva* was common in Aulavik National Park, Banks Island, N.W.T., Canada along the Thomsen River, between 73°13.49′ N, 199°32.12′ W and 73°36.2′ N, 120°2′ W, as well as at other sites in the park.

Methods

At the site on Banks Island, beside the Thomsen River (73°46′ N, 119°56.7′ W), on 10 July 1999, plants were growing in a series of shallow pools 10–70 cm deep surrounded by wet sedge meadows predominantly of *Eriophorum angustifolium* Honck. In this pool, most of the new season's growth was submerged leaves that if they reached the surface, floated parallel to it. Some plants had culms emerging from the water and developing short, aerial leaves. A sample of each growth form was collected and preserved as a herbarium specimen that was deposited at the Canadian National Herbarium (CAN 582410, Figure 1).

Beside the tundra pools were pieces of detached straw of the previous season's growth that were often lying on the damp moss, *Hamatocaulis vernicosus* (Mitt.) Hidenäs. Most of the straw was dead. Occasionally, new season's growth, in the form of leafy shoots, was observed at the top of some of the

FIGURE 1. Herbarium specimen of plants collected N.W.T., Banks Island, Aulavik National Park, 73°46′ N; 119°56′ W, 10 July 1999, *S. G. Aiken 99-230* (CAN 582410). Left, submerged plant with thin, flexuous, aquatic leaves and long rhizomes; right, plant developing characteristically distichous, more rigid, emergent leaves.

FIGURE 2. Voucher herbarium specimens collected N.W.T., Banks Island, Aulavik National Park, 73°46′ N; 119°56′ W, 10 July 1999, S. G. Aiken 99-230c (CAN 582408). Left, two typical pieces of previous season's straw 25-30 cm long. Right, a stem approximately 1 m long, developing new season's growth at the apex. Note that the remains of the previous season's leaves approximately 15 cm long have ends that might be interpreted as chewed.

pieces of stranded straw. Samples were collected and preserved as a herbarium specimen (CAN 582408, Figure 2). Twenty-six additional detached stems with new growth, along with some of the moss on which stems were lying, were collected. They were transported to Banks Island, Sachs Harbour, 71°59′ N, 125°20′ W, on 13 July 1999 where the straw was sorted into 13 approximately matched pairs of stems of similar length, width, and shoot development. One set remained in Sachs Harbour and the other set was transported to a private home in Ottawa-Carleton, Ontario, 45°16′ N, 75°46′ W. In both locations, the moss was placed in the bottom of a shallow container and the stems were laid on top. Pond or rainwater was used to saturate the moss to duplicate the conditions where the samples were collected. The containers were placed outdoors in Sachs Harbour on 14 July, where temperatures were 1–3°C, and there was 24–hour daylight and in Ottawa on 16 July, where temperatures were 17–32°C, and there was a day-night cycle. Observations were made as the season progressed. When it appeared that lack of nutrients may be limiting growth, a 10 cm layer of soil was placed under the moss on which the culms were lying.

Results

Description of aquatic leaves in A. fulva.

Aquatic or submerged leaves are long, narrow, and pale pinkish brown. They look similar to the aquatic leaves of the grass *Pleuropogon sabinei* R.Br. (image, Aiken et al. 2000*). The leaves were suspended in water like those of the aquatic leaves of wild rice *Zizania palustris* (Aiken et al. 1988). Submerged leaves have **sheaths** that are translucent, pale pinkish brown, closed to near the apex. Cells are developed on 50-60% of the sheath circumference. These are larger in the middle of the tissue and small before a thin translucent membrane that forms the remaining portion of the circumference. In surface view cells are readily visible, 2–4.5 mm long, 0.2–0.3 mm wide, and with prominent end walls. **Ligules** are adnate to the blade for 3–6 mm and taper to an acute tip from the blade margins to the midvein. The free ligule surface is uniformly about 0.5 mm wide, with the abaxial surface glabrous and the margin entire. The ligules are more like those of the Cyperaceae than the Poaceae. **Collar** position is inconspicuous. **Blades** are 8–25 cm long, 0.1–0.4 cm wide, translucent, pinkish brown and limp if removed from the water. Leaf cells, visible in surface view, are up to 7 mm long, 0.2–0.3 mm wide with prominent end walls. In **leaf cross section,** the midvein is slightly larger than the 8–14 adaxial to abaxial girders, 4–7 on either side of the midvein. The adaxial surface epidermis is one cell thick; the abaxial surface has a single layer of colorless epidermal cells and above them a single layer of cells containing chlorophyll. Between the epidermi and the girders are large air spaces. There is a slight develop-

ment of cell thickening at both ends of each girder, but this is not enough to influence the outline of blade surfaces that are uniform in cross section. The aquatic leaves observed when the specimens were collected have not been described previously in North American plants and none was found among circumpolar specimens of *A. fulva* examined by Aiken at Kew Herbarium (England, October, 2000).

Transition and emergent leaves

These were beginning to form on shoots that had started to emerge by 10 July 1999 and had relatively stiff leaves less than 10 cm long above the water surface. Leaves formed near the water surface were opaque and greenish brown. Aerial leaves of *A. fulva* have opaque **sheaths** that are green, brownish green, or sometimes reddish, and open to the base. The margins are not conspicuously membranous except near the sheath apex where the ligule margins are decurrent; cells and cell end walls are not visible. **Ligules** are free from the surface of the blade, 2–3 (-4) mm long slightly higher at the blade margins with the abaxial surface minutely scaberulous and the apex truncate, lacerate, and ciliolate. The ligule is similar to that found in some other arctic Poaceae (e.g., *Arctagrostis latifolia* Aiken et al. 2000*). **Collars** are conspicuous as a zone of contrasting colour on the abaxial surface between the sheath and the blade. They become more conspicuous in older leaves, up to 3 mm wide at the margins, and narrow at the midvein. **Blades** of the first aerial leaves are 3.5–4 (-6) cm long and become 10–15 cm long near the inflorescence, 0.2–0.8 cm wide, opaque, green, spreading stiffly at angles of 45–65° from the culm. The position of the vascular bundles is conspicuous as ribs on both leaf surfaces, with a lighter colour over the ribs, but leaf cells are not visible. In **leaf cross section,** the midvein is often inconspicuous in surface view, only slightly larger than the 6–23 adaxial to abaxial colorless girders. The leaves have typical C_3 anatomy with zones of chlorenchyma between the bundles. Vascular bundles in girders are slightly deeper than the chlorenchyma zones between the bundles. On top and bottom surfaces of the girders are prominent, bubbly zones of compact colorless parenchyma. In these positions, the outline of the leaf cross-section has conspicuous contours on both surfaces and is 3–4 times as wide as in the zones between ribs.

Last year's dead straw

Detached stems that had blown to the shoreline of the tundra were usually 20–50 cm long, but one measured 1 m long (CAN 582408, Figure 2). This stem was conspicuously longer than any other grass stems seen in Aulavik National Park and may have been growing in relatively deep water. There was no evidence that the *A. fulva* stems had flowered the previous season. Rather, where flowering may have occurred the remains of the previous season's leaves might be interpreted as having been chewed (Figure 2). A photograph of the new growth developing at the end of the detached stems shows the colour contrast between the previous season's straw colored remains and the news season's growth that is both reddish and fresh green (image Aiken et al. 2000*). On 10 July, none of the nearly 30 sprouting stems collected had developed roots.

Ontario, Ottawa-Carleton. Maximum temperatures between 16–23 July 1999, were between 27–32°C. By 18 July, one transplanted stem had sprouted a new shoot from a stem internode, and two days later, the first root appeared. Five days later, two of the terminal growing shoots were more than 10 cm high with new green growth. By 23 July, there were 24 actively growing shoots, the original terminal 13 shoots and 11 new shoots developing at culm nodes. Some were less than 1 cm long; the two longest shoots were about 15 cm long and curved upwards (Figure 3A). After this, no increase in height occurred in spite of warm temperatures in August. At the end of August the largest shoots were collected and preserved as herbarium specimens. Significant development of rhizomes and roots occurred below the moss surface during August (Figure 3B) and there was an increase in the number of new shoots produced at nodes along the previous season's growth until 30 August when a total of 51 shoots were present. Examination of a longitudinal section through apparently dead straw of the previous season's growth (Figure 4), indicated the stems were brown outside and inside, with little culm wall, and hollow on the inside except at the narrow node from which the new shoots were developing. On 30 August, the largest new stem that had developed was harvested and preserved as CAN 582407.

Banks Island, Sachs Harbour. Maximum temperatures between 14–24 July 1999, were between 2.6–13°C. By 24 July, many shoots had begun to grow and had red and green leaves. By 24 July, the longest shoot and root were 5 cm and 7 cm long, respectively. There followed two weeks of sunny weather with no rain during which the water in the container dried out, the moss turned brown and many shoots died. By 11 August, there were still 13 shoots alive, some terminal and some developing at nodes. The longest shoot was 8 cm and that was the maximum height reached. By 23 August, there was little sign of more above ground growth and on 31 August, the longest shoot was harvested and preserved as CAN 582556.

Additional field and herbarium observations

Observations and voucher specimens were collected in 1999 and 2000 in the course of Parks Canada patrols made in Aulavik National Park. Figure 5 was photographed on Banks Island, at Castel Bay, 74°12′N, 119°37′W, on 1 August 1999.

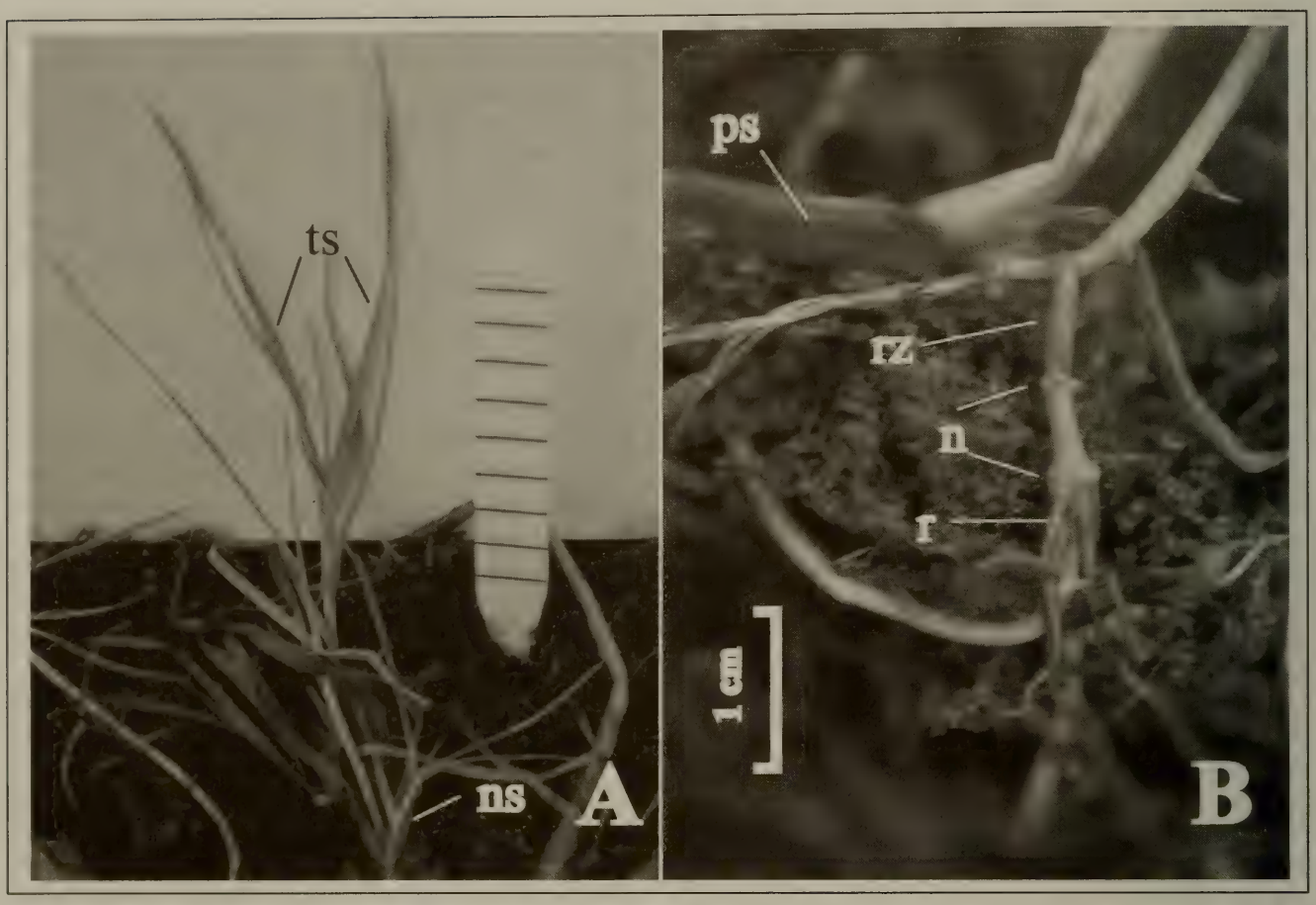

FIGURE 3. A. Close-up of the terminal end of a leafy shoot approximately 15 cm high that had developed in Ontario by 1 August 1999, from a vegetatively propagating piece of straw collected on Banks Island. Scale bar in cm. B. Close-up of new season's underground growth developing from a node of a previous season's culm (ps). Note branching rhizome (rz) with a ring of roots (r) developing from a node (n).

It shows a vegetative propagule that had developed vigorously growing rhizomes and roots. There are vouchers for observations made at other three other locations in Auluvak National Park, CAN numbers 582894 – 582896. A table summarizing other field observations that were made during Parks Canada patrols in 1999 and 2000 has been place with the specimens in the *A. fulva* folder, along with notes documenting the occurrence of Muskoxen (*Ovibos moschatus* Zimmerman) and Brant Geese (*Branta bernicula* L.) in the area. In 2001, a field trip in July and early August that focused on collecting *A. fulva* and *Duponita fisheri* R.Br., visited Churchill, Manitoba; Coral Habour, Southampton and Cornwallis Islands, Nunavut; Tuktoyaktuk, and Prince Patrick Island, Northwest Territories. At none of these places was there any evidence of aquatic leaves or vegetative propagules in either grass species.

Discussion

Aquatic leaves

The aquatic leaves in *A. fulva* observed on Banks Island were possibly more obvious because plants were growing in water that was relatively deep, not much above freezing, and was still cold around 10 July. Initial growth had been slow and in water where the level had not dropped through drying out as occurs in shallow ponds on Continental North America. The first author observed *A. fulva* in a drained lake-bed on Richard's Island, Northwest Territories, 69°20′N, 134°30′W, in 1988, where it was the dominant species. The plants were growing in damp moss and mud, where there had probably not been much depth of water in the spring, temperatures had been as much as 15°C warmer on average than on Banks Island during June, and growth of aerial stems appeared to have been rapid. If the relatively delicate submerged leaves had ever developed, they were no longer visible.

Propagules

That reserves in detached stems were utilized to develop new shoots from living cells that had not been killed in the severe winter is a phenomenon not known in other Arctic grasses. The vegetative development of the transplanted stems kept on Banks Island and those in Ottawa-Carleton, as well as the vegetatively propagating specimen found at Castel Bay (Figure 5) and other field observations indicate that under some environmental conditions *A. fulva* can propagate vegetatively from detached stems.

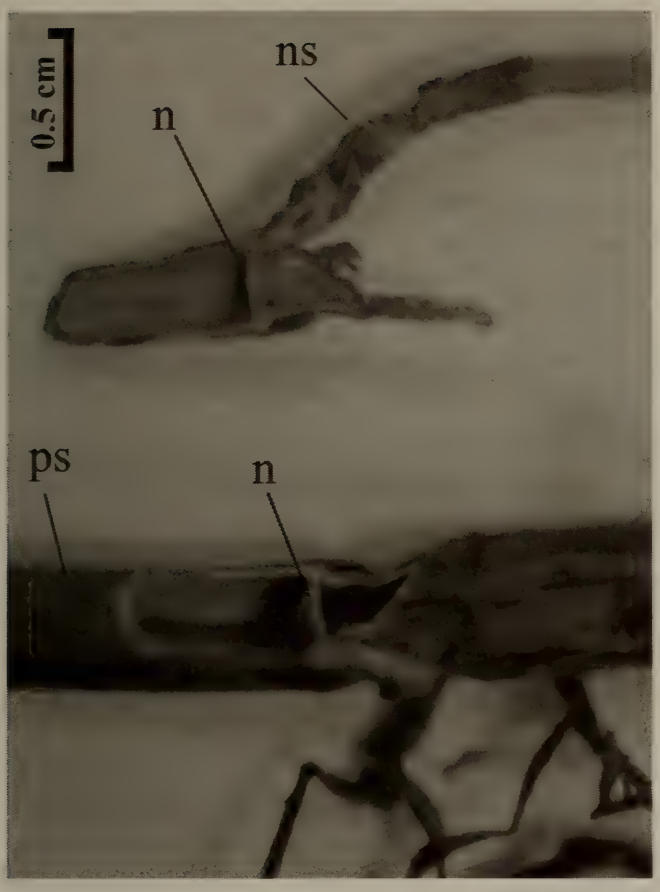

FIGURE 4. A specimen cut longitudinally through the node where a new shoot (ns) was developing. Upper portion with the base of the new leafy stems (ns) was arising at the node (n) of an otherwise hollow stem. Lower portion is the other side of the stem above. The previous season's stem (ps) is hollow, and the node (n) is a solid partition across the hollow stem.

FIGURE 5. A piece of previous season's straw successfully vegetatively proliferating. It had two rhizomes up to 12 cm long by 1 August, on Banks Island on the coast of Castel Bay, 74°12′ N; 119°37′ W.

The lack of roots on the sprouting shoots when they were collected was probably a reflection of an environment where moisture was not limiting growth. Early in development, the need of the straw of *A. fulva* to develop photosynthetic tissue was apparently greater than the need to develop roots. Although a very different system, the seeds of wild rice (*Zizania palustris*) germinating where water is not limiting, also develop photosynthetic tissue before producing roots. (Aiken, 1986). The contrast in the growth response between the samples observed on Banks Island and those observed in Ottawa probably reflects the difference in temperatures at the two locations. The difference in light quality or day-length may have been responsible for the new growth in Ottawa quickly turning green, while the new growth in plants on Banks Island remained reddish. In the Ontario transplant, *A. fulva* behaved as a periodic species (that is, one in which development is halted at a particular stage even when abundant opportunity for further growth remains (Sorenson 1941). It might have been tempting to interpret the plants as a genetically dwarfed arctic race of the species towards the northern limit of its distribution (Saville 1972) had it not been for the previous season's stem 1 m long (Figure 2).

The detached stems behaved somewhat like detached stems of Eurasian Water Milfoil (*Myriophyllum spicatum* L.) that will sometimes strand on damp mud, put out roots, and develop small terrestrial plants. But in that species, the growth occurs in the same growing season (Aiken et al. 1979). The specialized over-wintering buds (turions) of the native water milfoils (*Myriophyllum sibiricum* Komorov and *M. verticillaturm* L.), propagate similarly (Aiken and Waltz 1979; Weber and Nooden 1974), but after food reserves have been stored in them as they develop.

Towards northern limits of distribution

Porsild's (1957) idea that plants of *A. fulva* growing near the northern limit of distribution of the species that had not flowered, may propagate vegetatively is supported by herbarium vouchers: (a) CAN 127454 (a collection from Banks Island, 73°24′ N, 117° W, *A.E. Porsild, 17645*, on the label of which he noted that the plants were growing in water by a shallow pond where perhaps they are always sterile) and (b) CAN 127453 (from Victoria Island, near 70°39′ N, 117°24′ W, made on 8 August 1946, *A.E. Porsild 17237*, on the label of which is noted that the sterile specimens were growing in 18″ (45 cm) of water, forming a margin around a pond and that the species is apparently always sterile here). Porsild did not entertain the idea that the flowering inflores-

cences may have been grazed off and given that the culm leaves become longer near the inflorescence the top of the culm is not as apparent as in other grasses.

There are records of *A. fulva* plants collected at similar latitudes that have flowers CAN 5357995 (Banks Island, Egg River 72°27′ N, 124°36′), CAN 535769 (Banks Island, Shoron Lake, 73°N, 124°18′ W) and CAN 203530 (the northernmost specimen from Prince Patrick Island 76°12′N).

Animal grazing

Arctophila fulva is utilized as a forage by Muskoxen and Brant Geese (CAN 220464 and Park Canada patrol observations in Aulavik National Park). It is possible that plants had begun to flower, or were flowering, but the inflorescences were removed by some of these animals, grazing. Gray (1987) described Muskoxen playing in water on Bathurst Island (where *A. fulva* does not occur). He had observed that animals would walk into the middle of a shallow pond, stand in the water and suddenly begin to head-toss, whirl around, jump and splash. If *A. fulva* was growing in such a pond, plants would likely be uprooted by such activities. The tundra pools observed on Banks Island would be ideal for such play and the large Muskoxen population on the island may well explain the large number of detached stems found around the margins of ponds. These may float to the surface, and later be blown to the shoreline of the ponds, where they over-winter. Possibly some stems are detached when they are actively growing and contain food reserves that otherwise, later in the season, would have been withdrawn to the rhizomes and roots with the onset of winter. Such reserves appear to have been available to initiate new growth the following season, in some detached stems. On both Banks and Victoria islands, Muskoxen and Brant Geese are common and their activities may contribute to *A. fulva* occasionally proliferating vegetatively from detached straw. When the phenomenon of straw from one season being able to sprout new plants in the next season was discussed with grass taxonomists at Kew, they were unaware of any other such occurrence and thought it most unlikely to happen in tropical or temperate areas (W. D. Clayton, S. M. Phillips, and S. A. Renoize, personal communication March 2002).

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Records of Northern Mockingbird, *Mimus polyglottos*, Occurrences in North Dakota During the Twentieth Century

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The Northern Mockingbird (*Mimus polyglottos*) is a common bird in the southern United States that has been expanding its breeding range into the northern United States and southern Canada. During the twentieth century, there were 128 reports of Northern Mockingbird occurrences in North Dakota, including 106 reports during the breeding season (15 April to 31 August) and 22 during the nonbreeding season (1 September to 14 April). The species has been largely absent from North Dakota from January through mid-April. Prior to the 1930s, there was only one record (1916) of the Northern Mockingbird in the state. Observations of Northern Mockingbirds in North Dakota increased markedly between the 1930s and 1990s. On average, there were 0.3 reports of mockingbirds per year in 1931-1940, 0.6 in 1941-1950, 1.1 in 1951-1960, 1.6 in 1961-1970, 2.4 in 1971-1980, 2.3 in 1981-1990, and 4.5 in 1991-2000. The species has been observed in North Dakota nearly annually since 1958. At least six reports during the twentieth century included evidence of nesting (nests or dependent young). Based on mockingbird records during the twentieth century, we designate the current status of the Northern Mockingbird in North Dakota as a rare spring migrant, rare summer visitant, casual nester, and a casual fall and winter visitant.

Key Words: Northern Mockingbird, *Mimus polyglottos*, distribution and abundance, North Dakota, population status, twentieth century.

The Northern Mockingbird (*Mimus polyglottos*) is a geographically widespread species with southern affinities in North America. Densities of the species are highest near the Gulf of Mexico and decline northward and westward (Price et al. 1995). During the twentieth century, the species expanded the northern limits of its range into the northern United States and southern Canada (Derrickson and Breitwisch 1992). Although mockingbirds are considered permanent residents throughout much of their historical range, mockingbirds are believed to be migratory in the northern portion of their range, including newly colonized northern regions (Brazier 1964; Stiles 1982; David et al. 1990; Derrickson and Breitwisch 1992).

Stevens (1947, 1948) summarized some of the earliest records of Northern Mockingbirds in North Dakota. Brazier (1964) reviewed the range expansion of the Northern Mockingbird in the northern Great Plains and provided updated and new information on the Northern Mockingbird in North Dakota. Stewart (1975) summarized historical occurrences of the species and categorized the Northern Mockingbird as a hypothetical breeder in the state. Little has been published on mockingbirds in North Dakota since Stewart's book. There has been a substantial increase in the number of reports of Northern Mockingbirds in North Dakota (e.g., Johnson and Johnson 1976), including confirmed nesting records (e.g., Child et al. 1980). In this paper, we summarize reported occurrences of Northern Mockingbirds in North Dakota during the twentieth century, review the species' current status and distribution within the state, and discuss factors influencing or limiting the species' expansion into the state.

Methods

Records of Northern Mockingbird occurrences in North Dakota were summarized from published and unpublished reports, including those in *Bird Lore*, *Audubon Magazine*, *Audubon Field Notes*, *American Birds*, and *National Audubon Society Field Notes*, and those filed with the North Dakota Birding Society (R. E. Martin and G. B. Berkey, North Dakota Birding Society, unpublished data). We also included data from Christmas Bird Counts (1909-1999; http://birdsource.cornell.edu/cbc/), North American Breeding Bird Surveys (1967-1999; Sauer et al. 2000; U.S. Geological Survey, Laurel, Maryland, unpublished data), and banding records from the Bird Banding Laboratory (1955-1998; U.S. Geological Survey, Laurel, Maryland, unpublished data). We defined a record as an occurrence of an individual, a breeding pair, or a group of Northern Mockingbirds. Records were summarized by date (decade and month) and location (county) of the observation. Details on nests or dependent young also were noted. Exact locations or dates are not known for a few records. Although some observations occurred over multiple days, weeks, or months,

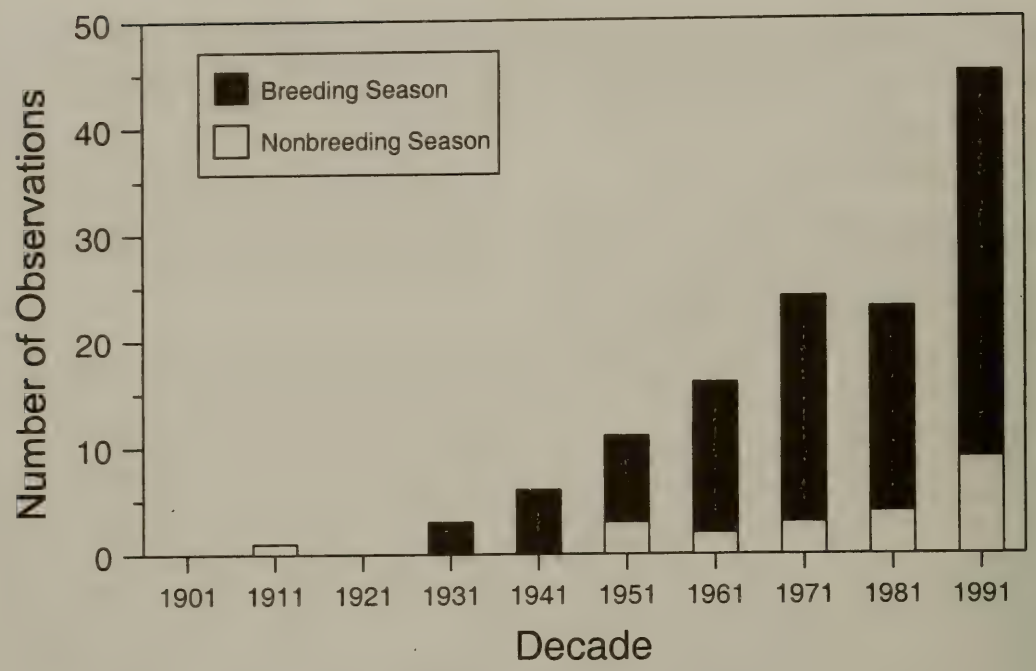

FIGURE 1. Records of Northern Mockingbird occurrences in North Dakota during the twentieth century, by decade (e.g., 1901 to 1910, 1991 to 2000). Dark = breeding-season records; light = nonbreeding-season records.

summaries within figures represent the date that the individual record was first observed. For purposes of discussion, observations between 15 April and 31 August were considered breeding-season records, and observations between 1 September and 14 April were considered nonbreeding-season records (Derrickson and Breitwisch 1992).

Results

During the twentieth century, there were 128 reports of Northern Mockingbirds in North Dakota (Appendix A). The number of individuals detected during a single observation ranged from one to four. Most of the observations involved single birds observed for only one or a few days.

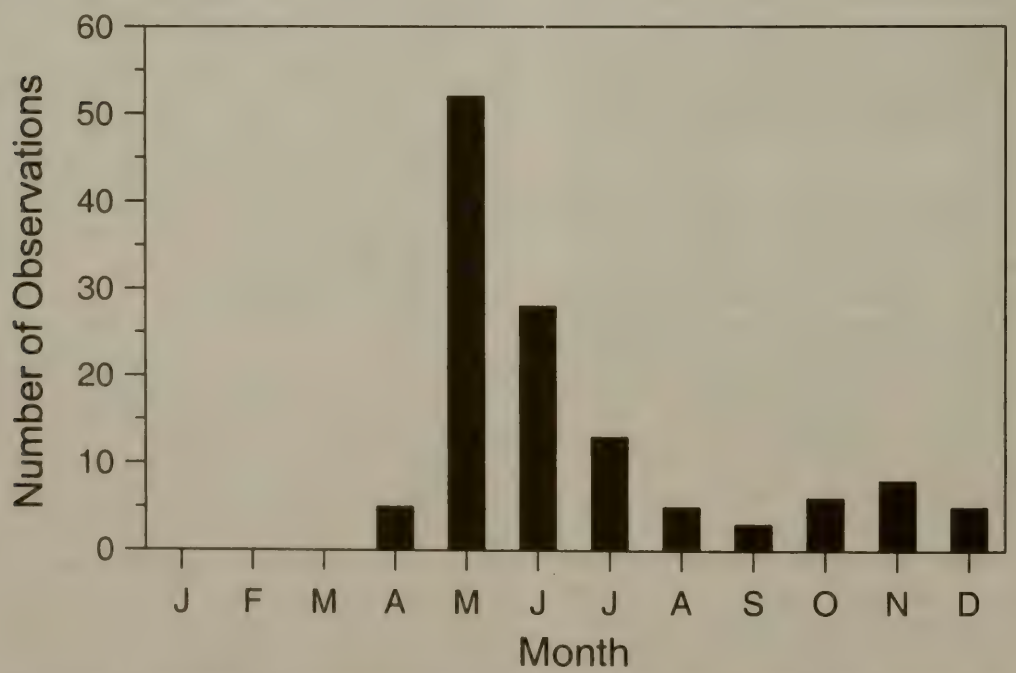

FIGURE 2. Records of Northern Mockingbird occurrences in North Dakota during the twentieth century, by month.

FIGURE 3. Northern Mockingbird nest found on 25 June 1998 in Kidder County, North Dakota (photograph by L. D. Igl).

The earliest confirmed record of a Northern Mockingbird in North Dakota was of an adult bird collected on 23 November 1916 by C. C. Smith on the campus of the University of North Dakota in Grand Forks (Grand Forks County) (Wood 1923). Wood (1923: 77) considered this bird to be an "accidental straggler." To our knowledge, there were no records of Northern Mockingbirds in North Dakota before that date. This observation also represented the first record of the species in the northern Great Plains during the nonbreeding season (Brazier 1964).

The second record of a Northern Mockingbird in North Dakota occurred over 17 years later on 17 May 1934 in Valley City (Barnes County) (Appendix A). This observation represented the first breeding-season record in the state and generally marked the beginning of the species' range expansion into North Dakota. Observations of mockingbirds increased markedly between the 1930s and 1990s (Figure 1). On average, there were 0.3 reports of mockingbirds per year in 1931-1940, 0.6 in 1941-1950, 1.1 in 1951-1960, 1.6 in 1961-1970, 2.4 in 1971-1980, 2.3 in 1981-1990, and 4.5 in 1991-2000. Since 1958, the species has been observed nearly annually in all but 3 of 43 years, with no records for 1962, 1983, and 1989.

Only 22 mockingbird occurrences were recorded during the nonbreeding season, mostly between October and December (Figure 2; Appendix A). Mockingbirds were largely absent from the state in January, February, and March. Only two mockingbirds have been observed in North Dakota during those months. Between 30 November 1972 and 14 April 1973, an injured mockingbird was observed in Fargo in Cass County. Between mid-December 1999 and 1 February 2000, a single mockingbird sporadically visited bird feeders about 6.4 km southeast of Jamestown in Stutsman County (M.A. Sovada, U.S. Geological Survey, Jamestown, North Dakota, personal communication).

About 83% (106 of 128) of the mockingbird observations occurred during the breeding season (mid-April through August) (Figure 2, Appendix A). Of the 106 reports of mockingbird occurrences in North Dakota during the breeding season, six (6%) involved nests or dependent young. Mrs. R. Nordbye (personal communication in Child et al. 1980) found a nest with young in Parshall (McLean County) in the summer of 1961. Near Richardton (Stark County), J. Hoff found nesting mockingbirds in July 1970, June 1988, and July 1995. Successful fledging of two successive broods in June and July 1980 was reported in Oakes in Dickey County (Childs et al. 1980). L. D. Igl found a breeding pair and a nest containing four eggs in a single-row shelterbelt in Kidder County on 25 June 1998 (Figure 3; Martin 1998). There also are

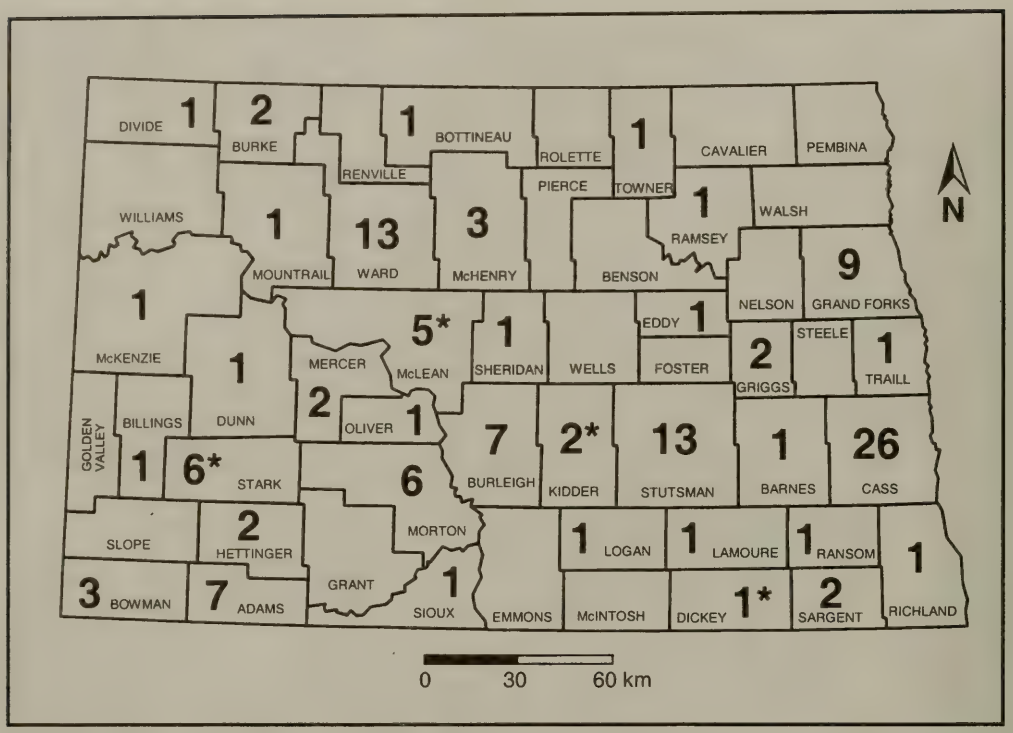

FIGURE 4. Records of Northern Mockingbird occurrences in North Dakota during the twentieth century, by county. Asterisk (*) denotes counties where nests or dependent young have been observed.

two references to mockingbirds nesting in North Dakota but without specific reference to date: A. C. Fox indicated that mockingbirds have been found nesting in Dickinson (Stark County; Stewart 1975), and R. L. Rytter noted adult mockingbirds feeding young in Kenmare (Ward County).

Northern Mockingbirds were observed in 36 (67.9%) of the 53 counties in North Dakota (Figure 4, Appendix A). Although more mockingbird observations occurred in the southern half than the northern half of North Dakota (Figure 4), the temporal pattern of expansion into North Dakota was sparse and sporadic rather than progressing from south to north (Appendix A). Counties with larger cities had more records of mockingbirds than less-populated counties. These included Bismarck in Burleigh County, Mandan in Morton County, Fargo in Cass County, Jamestown in Stutsman County, Minot in Ward County, Dickinson in Stark County, and Grand Forks in Grand Forks County. The largest number of records (n = 26) in a county occurred in Cass County, with most occurrences being from Fargo, the largest metropolitan area in North Dakota. The distribution of mockingbird records within the state also may reflect the distribution of observers in North Dakota. For example, there were seven records of mockingbirds in Adams County in southwestern North Dakota, all made by C. Griffiths and/or D. Griffiths.

The North American Breeding Bird Survey (BBS) is a program of standardized roadside surveys administered by the U.S. Geological Survey and conducted by experienced or knowledgeable volunteers, usually in June. BBSs have been conducted in North Dakota since 1967; there are currently 44 active routes in the state. Northern Mockingbirds were recorded on 5 of 983 (<1%) surveys of BBS routes that were conducted in North Dakota between 1967 and 1999, including one year each on the Parshall (McLean County), Denbigh (McHenry County), and Sheyenne Lake (Sheridan County) routes and two years on the Bentley (Hettinger County) route (Appendix A). The first occurrence of a mockingbird on a BBS route was on the Parshall route on 19 June 1985.

Sponsored by the National Audubon Society, Christmas Bird Counts (CBCs) are conducted annually throughout North America. The main goal of the CBC program is to monitor bird populations during early winter (late December to early January). CBC circles are frequently placed where the greatest concentrations of wintering birds occur and often are placed near towns and cities. CBCs have been conducted in North Dakota since the early part of the twentieth century. The first CBC in North Dakota occurred in Fargo in 1909 (Chapman 1910); one or more CBCs have been conducted nearly annually in North Dakota since then. Mockingbirds have been reported on 4 of 682 (<1%) CBCs in North Dakota between 1909 and 1999, including three years on the Bismarck-Mandan CBC and one year on the Fargo-Moorhead CBC (Appendix A). Mockingbirds also

were reported within the Count circle during the week of the CBC but not the day of the CBC in Fargo (Cass County) in 1972 and in Jamestown (Stutsman County) in 1999. The earliest occurrence of the species on a CBC was in Bismarck (Burleigh County) on 20 December 1956.

To our knowledge, only four Northern Mockingbirds have been banded in North Dakota. A mockingbird was banded by H. R. Gray in Wilton (McLean County) on 3 June 1943 (Stevens 1948). Of 610 066 birds banded in North Dakota between 1955 and 1998 (all species combined), three were Northern Mockingbirds banded in 1960, 1964, and 1971 by R. T. Gammell and A. M. Gammell (Bird Banding Laboratory, U.S. Geological Survey, Laurel, Maryland, unpublished data).

Discussion

The available data suggest that North Dakota currently supports a small but growing population of Northern Mockingbirds. Spring arrival in North Dakota begins in mid-April and continues into May (Figure 2), and available evidence suggests that nesting occurs largely in June and July. One or two broods are possible, but rare, in North Dakota. Few mockingbirds have overwintered in the state, which, along with the influx of mockingbirds in spring, suggests that this species is migratory in North Dakota. However, most of the North Dakota observations were of single birds, and to our knowledge, most birds were observed or present for only one or a few days. Observations of mostly single birds and the general scarcity of nesting suggests that most mockingbirds observed in North Dakota were probably wandering rather than nesting birds. Mockingbirds are noted for their behavioral plasticity and wandering behavior (Derrickson and Breitwisch 1992).

Many records of mockingbird occurrences in North Dakota were from scattered or random observations by one or a few observers. Most observations occurred in spring or summer, and many observations occurred in or near human population centers. Admittedly, these records may be biased by the activity and locations of observers (i.e., most birding occurs in spring and summer and most bird observations are made in residential areas). Apparent increases in North Dakota during the twentieth century also may reflect higher observer effort or more qualified observers. However, mockingbirds are a conspicuous and easily detected species. Mockingbirds strongly defend their territories during both the nonbreeding and breeding seasons, vocalize loudly and elaborately, and often are associated with human residential areas. Thus, increases in mockingbird populations based on individual records probably track statewide trends.

Changes in mockingbird populations in North Dakota also coincide with similar patterns of range expansion in other states and Canadian provinces. During the twentieth century, the species has expanded its range northward in California (Arnold 1980), Michigan (Dziepak 1991), New York (Bull 1974), Ontario (Curry 1987), Quebec (David et al. 1990), Saskatchewan (Smith 1996), and Wisconsin (Robbins 1991). There are scattered records of mockingbirds in states adjacent to North Dakota, including Montana (MBDC 1996), South Dakota (SDOU 1991), and Minnesota (Janssen 1987). In western Illinois, the species was historically an irregular migrant until the mid-1930s, when it became common (Bohlen 1989). Mockingbirds were sparse in Iowa until the 1930s (Spess Jackson et al. 1996); the species is now considered a rare summer resident with higher densities in the southern portion of the state (Kent and Dinsmore 1996).

Factors thought to contribute to the species' northward range expansion in North America include increased availability of suitable nesting habitat (trees and shrubs) and increased availability of food (e.g., fruit-bearing trees and shrubs, suet feeders). Northern Mockingbirds favor brushy areas and woodland edges, and often are associated with ornamental plantings in residential areas (Derrickson and Breitwisch 1992) and shelterbelts and scattered trees and shrubs in agricultural areas (Versaw 1998).

The abundance and distribution of woody vegetation have changed dramatically in North Dakota since this region was first settled by Europeans in the mid to late 1800s. Since settlement, there have been repeated efforts to establish tree plantings in North Dakota and other areas in the Great Plains (Hart and Hart 1997). Fire suppression also encouraged the encroachment and establishment of woody vegetation into open grasslands in this region. Between 1935 and 1942, 38 million trees were planted in 13 760 ha of shelterbelts and windbreaks (Haugen 1999). Since the Dust Bowl, more than 142 000 km of field windbreaks and 115 000 ha of protection tree plantings have been established in North Dakota. It is probable that the planting of shelterbelts and windbreaks in North Dakota in the early part of the twentieth century provided the habitat necessary and impetus for the Northern Mockingbird's northward expansion into North Dakota. Presently, there does not appear to be a shortage of suitable breeding habitat for Northern Mockingbirds in North Dakota.

Fruit is a critical component of the mockingbird's diet during the fall, winter, and spring (Derrickson and Breitwisch 1992). Stiles (1982) speculated that the species' northward expansion into the northeastern U.S. may have been related to the plantings of multiflora rose (*Rosa multiflora*). In the northern Great Plains, mockingbirds have been observed feeding on fruit from several common fruit-bearing trees and shrubs including honeysuckle (*Lonicera* spp.), Russian Olive (*Elaeagnus angustifolia*), and

apple (*Malus* spp.) (Brazier 1964). In other areas, the species has been observed eating fruit from hawthorn (*Crataegus* spp.), crabapples (*Pyrus* spp.), and Eastern Redcedar (*Juniperus virginiana*) (Arnold 1980; Stiles 1982), all of which occur in North Dakota. Dziepak (1991) indicated that suet feeders and ornamental plantings of fleshy-fruited shrubs may have helped the species expand its range into Michigan, but these food resources were not sufficient to sustain the species through Michigan's severe winters.

Northern Mockingbirds are largely absent from North Dakota during the winter. Overwintering also is rare in other northern regions (e.g., Saskatchewan; Smith 1996), suggesting that mockingbirds withdraw from these areas for the winter or succumb to winter conditions. Dziepak (1991) and others have suggested that winter weather is likely the chief factor limiting the distribution of this species at the northern edge of its range. Root (1988) proposed that a physiological limit on metabolic rate constrains the northern limit of wintering North American birds, and demonstrated that mockingbirds typically overwinter in areas that have an average minimum January temperature of –7°C or higher. The average January temperature in North Dakota ranges from –16.7°C in northeast North Dakota to –8.3°C in southwest North Dakota (Jensen 1972). Repasky (1991), however, argued that the northern boundary of a species would occur at the point where sufficient food cannot be obtained to offset the greater energy demand of colder temperatures. Brazier (1964) noted many records of dead mockingbirds found during winter in the northern Great Plains. In Illinois, mockingbirds have suffered massive reductions in population during severe winter weather (Bohlen 1989). The success of the species' range expansion into northern areas will likely be determined by the species' ability to develop stronger migratory habits or to cope with the harsh winter conditions and limited food resources in northern regions.

Based on mockingbird records of occurrence in North Dakota during the twentieth century, we designate the current status of the Northern Mockingbird in North Dakota as: (1) a rare spring migrant (i.e., a species that occurs annually in North Dakota in low numbers during spring), (2) a rare summer visitant (i.e., a species that wanders or oversummers annually in low numbers in North Dakota during the normal breeding period), and (3) a casual fall and winter visitant (i.e., a species that occurs less than annually in North Dakota during fall or winter). Although there were very few nesting records in North Dakota during the twentieth century, we also recommend that the species' nesting status in North Dakota be changed from "hypothetical breeder" (Stewart 1975) to "casual nester" (i.e., a species for which a viable clutch of eggs, dependent young in the nest, or dependent young that have left the nest have been observed less than annually in North Dakota). Continued monitoring of mockingbirds should provide insight into the dynamics of the species' range expansion into North Dakota and elsewhere in the northern Great Plains. Future increases or changes in the species' distribution and abundance in North Dakota will necessitate a re-evaluation of the species' status.

Acknowledgments

Over the years, many people have contributed records of Northern Mockingbirds in North Dakota. We thank all of them. We are especially grateful to Gordon B. Berkey and David O. Lambeth for their dedication to North Dakota birdlife, for their commitment to the North Dakota Birding Society, and for compiling bird records for the state from the mid-1970s to the mid-1990s. This paper has benefitted from the thoughtful comments of G. B. Berkey, F. R. Cook, A. J. Erskine, C. S. Houston, D. H. Johnson, H. T. Sklebar, and M. A. Sovada.

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APPENDIX A.

Location, date(s), observer(s), season (nonbreeding or breeding), and number of birds observed for reported occurrences of Northern Mockingbirds in North Dakota during the twentieth century. Data were summarized from published and unpublished (R. E. Martin and G. B. Berkey, North Dakota Birding Society) reports.

No.	Location	Date(s)	Observer(s)	Season[a]	Number of birds
1.	Grand Forks, Grand Forks County	23 November 1916	C. C. Schmidt (Woods 1923)	Nonbreeding	one (collected)
2.	Valley City, Barnes County	17 May 1934	Observer not specified (from the files of the North Dakota Birding Society)	Breeding	one
3.	Dickinson, Stark County	Summer 1938	R. W. Smith (Stevens 1947)	Breeding	one
4.	Dickinson, Stark County	May 1939	R. W. Smith, F. C. Butcher, and F. G. Butcher (Stevens 1947)	Breeding	one
5.	Fargo, Cass County	12-13 May 1942	Mrs. W. E. Brentzel	Breeding	one
6.	Rock Lake, Towner County	31 May 1943	Ambrosen and Dinkins (Hammond 1943)	Breeding	one
7.	Minot, Ward County	1-2 June 1943	E. A. Hibbard (Stewart 1975)	Breeding	one
8.	Wilton, McLean County	3 June 1943	H. R. Gray (Stevens 1948)	Breeding	one (banded)
9.	Fargo, Cass County	21-28 July 1946	O. A. Stevens and H. G. Heggeness (Stevens 1947)	Breeding	one
10.	Minot, Ward County	1-2 June 1948	S. Saugstad (Stewart 1975)	Breeding	one
11.	Mandan, Morton County	24-25 May 1952	R. N. Randall	Breeding	one
12.	Kenmare, Ward County	1-14 June 1952	R. T. Gammell and A. M. Gammell (Gammell and Gammell 1952)	Breeding	one
13.	Bismarck, Burleigh County	8 June 1952	R. N. Randall (Baumgartner 1952)	Breeding	one
14.	Fargo, Cass County	13 May 1953	J. F. Cassel (Gammell and Gammell 1953)	Breeding	one
15.	Des Lacs National Wildlife Refuge, Ward County	4-7 October 1955	H. S. Huenecke (Gammell and Huenecke 1956)	Nonbreeding	one
16.	Southeast of Kenmare, Ward County	18 May 1956	V. Rytter (Gammell 1956)	Breeding	one
17.	Mandan, Morton County	30 December 1956	Bismarck-Mandan Christmas Bird Count (Cruickshank 1957)	Nonbreeding	one
18.	Parshall, McLean County	4-11 November 1958	Dr. and Mrs. R. Nordbye; R. T. Gammell and A. M. Gammell (Krause 1959)	Nonbreeding	one
19.	Des Lacs National Wildlife Refuge, Ward County	23 August 1959	A. M. Gammell (Krause 1960)	Breeding	four
20.	Ward County	6 May 1960	R. T. Gammell	Breeding	one (banded)
21.	Kenmare, Ward County	25-28 May 1960	R. L. Rytter and D. Rytter (Gammell 1960)	Breeeding	one each at three locations
22.	Parshall, McLean County	Summer 1961	Mrs. R. Nordbye (personal communication *in* Child et al. 1980)	Breeding	nest with young
23.	Mandan, Morton County	29 December 1963	Bismarck-Mandan Christmas Bird Count (Cruickshank 1964)	Nonbreeding	one
24.	Ward County	1 May 1964	R. T. Gammell	Breeding	one (banded)
25.	Bismarck, Burleigh County	10 May 1964	R. N. Randall	Breeding	one
26.	Fargo, Cass County	13 June 1965	Mrs. F. B. Scheel (Hatch 1965)	Breeding	one
27.	Near Binford, Griggs County	June 1966	R. E. Stewart, Sr. (Stewart 1975)	Breeding	one

(Continued)

APPENDIX A. *(continued)*

No.	Location	Date(s)	Observer(s)	Season[a]	Number of birds
28.	Hankinson, Richland County (T130N, R50W)	12 July 1966	R. E. Stewart, Sr. (Stewart 1975)	Breeding	one
29.	North of Fargo, Cass County	30 April-19 May 1967	R. Kroodsma	Breeding	one
30.	Bismarck, Burleigh County	20 May 1967	R. N. Randall	Breeding	one
31.	Fargo, Cass County	22-23 May 1967	Observer not specified (from the files of the North Dakota Birding Society)	Breeding	one
32.	Rhame, Bowman County	20 June 1967	R. E. Stewart, Sr. (Stewart 1975)	Breeding	one
33.	Fargo, Cass County	13 September 1967	Observer not specified (from the files of the North Dakota Birding Society)	Nonbreeding	one
34.	Arrowwood National Wildlife Refuge, Stutsman County	21 April 1968	J. T. Lokemoen and P. F. Springer	Breeding	one
35.	Des Lacs National Wildlife Refuge, Ward County	8 May 1968	A. M. Gammell	Breeding	one
36.	Fargo, Cass County	20 December 1969	Fargo-Moorhead Christmas Bird Count (Cruickshank 1970)	Nonbreeding	one
37.	North of Richardton, Stark County	July 1970	J. Hoff	Breeding	two + young
38.	Audubon National Wildlife Refuge, McLean County	8-9 May 1971	D. C. McGlaughlin (Houston 1971)	Breeding	one
39.	Montpelier, Stutsman County	11, 13-15 May 1971	L. C. Haynes (Houston 1971)	Breeding	one + one
40.	Bowman, Bowman County	15 May 1971	J. Oberfoel (Houston 1971)	Breeding	one
41.	Kenmare, Ward County	3 August 1971	R. T. Gammell	Breeding	one (banded)
42.	Gackle, Logan County	16 May 1972	G. L. Krapu	Breeding	one
43.	Jamestown, Stutsman County	4 June 1972	M. L. Avery (Stewart 1975)	Breeding	one
44.	Fargo, Cass County	12 September 1972; 30 November 1972 to 14 April 1973	A. M. Bolin (Houston and Houston 1973), also reported on Fargo-Moorhead Christmas Bird Count during Count week (Arbib et al. 1973)	Nonbreeding	one (injured)
45.	Bismarck, Burleigh County	28 May 1973	R. N. Randall (Houston 1973)	Breeding	one
46.	Cooperstown, Griggs County	6 July 1973	D. L. Kubischta	Breeding	one
47.	Fargo, Cass County	8 August 1973	Observer not specified (from the files of the North Dakota Birding Society)	Breeding	one
48.	Bismarck, Burleigh County	26 May 1974	B. Quanrud	Breeding	one
49.	Kulm, LaMoure County	10 May 1975	Observer not specified (from the files of the North Dakota Birding Society)	Breeding	one
50.	Jamestown, Stutsman County	18 May 1976	D. H. Johnson and J. E. Johnson (Johnson and Johnson 1976)	Breeding	one
51.	Fargo, Cass County	25 May 1976	J. F. Cassel (Serr 1976a)	Breeding	one
52.	Fargo, Cass County	22 June to 11 July 1976	V. J. Schell (Serr 1976b)	Breeding	one
53.	Sargent County	29 June 1977	R. Schmidt, J. Herman, and K. Wilson	Breeding	one
54.	Hensler, Oliver County	3 July 1977	R. N. Randall	Breeding	one
55.	Fargo, Cass County	3 November 1977	C. Brakke	Nonbreeding	one
56.	Fargo, Cass County	5-30 November 1977	A. Lies	Nonbreeding	one
57.	Crosby, Divide County	19 May 1978	R. A. Stromstad (Serr 1978)	Breeding	one
58.	Upper Souris National Wildlife Refuge, Ward County	27 May 1979	I. O. Rostad (Serr 1979a)	Breeding	one
59.	Northern Prairie Wildlife Research Center, Stutsman County	5-16 July 1979	C. A. Faanes and other Center staff (Serr 1979b)	Breeding	one
60.	Grand Forks, Grand Forks County	6-7 May 1980	J. Van Rybroek (Serr 1980)	Breeding	one
61.	Oakes, Dickey County	8 June to 25 July 1980	D. Child, J. Fontaine, T. Gatz, M. Johnson, and J. Oswald (Child et al. 1980)	Breeding	two + two nests (totaling 8 young)

(Continued)

APPENDIX A. *(continued)*

No.	Location	Date(s)	Observer(s)	Season[a]	Number of birds
62.	Fargo, Cass County	3-18 November 1981	M. A. Bergan and C. A. Spurbeck (Lambeth 1982)	Nonbreeding	one
63.	Grand Forks Air Force Base, Grand Forks County	19 May 1982	J. F. Kelly (Berkey 1982)	Breeding	one
64.	Mercer County	22 July 1982	C. A. Faanes (Faanes 1983)	Breeding	one
65.	Fargo, Cass County	11 May 1984	M. A. Bergan and C. A. Spurbeck (Berkey 1984)	Breeding	one
66.	Fargo, Cass County	21 June 1984	M. A. Bergan and C. A. Spurbeck	Breeding	one (injured)
67.	Mandan, Morton County	27 October 1984	J. Swanick and O. Swanick (Lambeth 1985)	Nonbreeding	one
68.	Fargo, Cass County	17 November 1984	T. Dahlen (Lambeth 1985)	Nonbreeding	one
69.	Lake Alice, Ramsey County	2 May 1985	R. W. Schnaderbeck	Breeding	one
70.	McLean County	19 June 1985	R. E. Martin (Parshall Breeding Bird Survey)	Breeding	one
71.	Hettinger, Adams County	28-29 April 1986	D. Griffiths and C. Griffiths	Breeding	one
72.	Fargo, Cass County	22 May 1987	L. L. Falk	Breeding	one
73.	New Town, Mountrail County	22-23 May 1987	R. A. Satermo and B. C. Houser	Breeding	one
74.	Sioux County	24 May 1987	R. Titus	Breeding	one
75.	McHenry County	21 June 1987	R. L. Rytter (Denbigh Breeding Bird Survey)	Breeding	one
76.	Grand Forks, Grand Forks County	Late June 1987	Observer not specified (from the files of the North Dakota Birding Society)	Breeding	two
77.	Eddy County	5 August 1987	R. Hill	Breeding	one
78.	Hettinger, Adams County	22 April 1988	D. Griffiths and C. Griffiths (Berkey 1988a)	Breeding	one
79.	J. Clark Salyer National Wildlife Refuge, McHenry County	13 May and 15 May 1988	W. Berg, R. E. Martin, and G. B. Berkey (Berkey 1988a)	Breeding	two
80.	Richardton, Stark County	June 1988	J. Hoff	Breeding	two + nest (with eggs)
81.	Fargo, Cass County	7 June to 11 July 1988	R. Kain (Berkey 1988b)	Breeding	one
82.	Grand Forks, Grand Forks County	25 October to 17 November 1988	D. O. Lambeth (Lambeth 1989)	Nonbreeding	one
83.	Hettinger, Adams County	31 May 1990	D. Griffiths and C. Griffiths (Lambeth 1990)	Breeding	one
84.	Lostwood National Wildlife Refuge, Burke County	9 July 1990	R. K. Murphy	Breeding	one
85.	Fargo, Cass County	10-14 May 1991	J. O. Hersch (Lambeth 1991)	Breeding	one
86.	Mercer County	29 May 1991	R. E. Martin (Lambeth 1991)	Breeding	one
87.	Bucyrus, Adams County	10 June 1991	D. Griffiths and C. Griffiths	Breeding	one
88.	Kelly's Slough National Wildlife Refuge, Grand Forks County	23 June 1991	E. E. Freeberg	Breeding	one
89.	Fargo, Cass County	11 May 1992	L. L. Falk	Breeding	one
90.	Kidder County	16 May 1992	M. A. Otnes	Breeding	one
91.	Jamestown, Stutsman County	18 May 1992	J. T. Lokemoen	Breeding	one
92.	Bowman County	24 May 1992	R. E. Martin and G. B. Berkey	Breeding	one
93.	Mirror Pool, Ransom County	19 July 1992	M. A. Otnes	Breeding	one
94.	Grand Forks, Grand Forks County	28 October to 30 November 1992	D. O. Lambeth	Nonbreeding	one
95.	Fried, Stutsman County	4 May 1993	J. T. Price and A. Price	Breeding	one
96.	Fargo, Cass County	10-19 May 1993	D. Wiesenborn	Breeding	one
97.	South of Bismarck, Burleigh County	15 May 1993	R. H. O'Connor, G. E. Nielsen, and M. A. Otnes	Breeding	one

(Continued)

APPENDIX A. *(continued)*

No.	Location	Date(s)	Observer(s)	Season[a]	Number of birds
98.	Sheridan County	13 June 1993	R. E. Martin (Sheyenne Lake Breeding Bird Survey) (Berkey 1993)	Breeding	one
99.	Hettinger County	19 June 1993	D. Griffiths (Bentley Breeding Bird Survey) (Berkey 1993)	Breeding	one
100.	Lostwood National Wildlife Refuge, Burke County	27 June 1993	E. M. Madden (Berkey 1993)	Breeding	one
101.	Bismarck, Burleigh County	20 December 1993	Bismarck-Mandan Christmas Bird Count (LeBaron 1994)	Nonbreeding	one
102.	Hettinger, Adams County	11 May 1994	D. Griffiths and C. Griffiths (Martin 1994)	Breeding	one
103.	Minot Sewage Lagoons, Ward County	18 May 1994	G. B. Berkey (Martin 1994)	Breeding	one
104.	Bottineau County	22 May 1994	R. E. Martin (Martin 1994)	Breeding	one
105.	Grand Forks, Grand Forks County	26 May 1994	D. O. Lambeth (Martin 1994)	Breeding	one
106.	Theodore Roosevelt National Park (South Unit), Billings County	5 June 1994	H. C. Talkington	Breeding	one
107.	McHenry County	5-12 June 1994	R. E. Martin	Breeding	two
108.	Hettinger, Adams County	13-29 July 1994	D. Griffiths and C. Griffiths	Breeding	one
109.	Northern Prairie Wildlife Research Center, Stutsman County	7 September to mid-November 1994	L. D. Igl, D. H. Johnson, and J. T. Price	Nonbreeding	one
110.	North of Cayuga, Sargent County	10 May 1995	K. Askerooth	Breeding	one
111.	Arrowwood National Wildlife Refuge, Stutsman County	13 May 1995	R. Ziarno	Breeding	one
112.	Near Richardton, Stark County	27 July 1995	J. Hoff (Berkey 1995)	Breeding	two + three fledglings
113.	Mandan, Morton County	15 November 1995	R. N. Randall	Nonbreeding	one
114.	McKenzie County	25 November 1995	B. Boyd	Nonbreeding	one
115.	Arrowwood National Wildlife Refuge, Stutsman County	10 May 1996	C. R. Luna	Breeding	one
116.	Fargo, Cass County	24 May 1996	D. Wiesenborn	Breeding	one
117.	Northern Prairie Wildlife Research Center, Stutsman County	10 June 1996	H. A. Kantrud	Breeding	one
118.	Fargo, Cass County	28 June 1997	C. R. Gjervold and R. Gjervold	Breeding	one
119.	Richardton, Stark County	19 July 1997	J. Hoff	Breeding	one
120.	Mandan, Morton County	15 April 1998	H. C. Talkington	Breeding	one
121.	Grand Forks County	16 and 18 May 1998	J. Maxwell and B. Maxwell	Breeding	one
122.	Hettinger County	1 July 1998	D. Griffiths (Bentley Breeding Bird Survey)	Breeding	one
123.	Kidder County	25 June 1998	L. D. Igl (Martin 1998)	Breeding	two + nest (with four eggs)
124.	New Hradec, Dunn County	27 October 1998	J. Lefor	Nonbreeding	one
125.	Portland, Traill County	30 October 1998	C. D. Ellingson	Nonbreeding	one
126.	Adams County	18 August 1999	D. Griffiths and C. Griffiths	Breeding	one
127.	Southeast of Jamestown, Stutsman County	Mid-December 1999 to 1 February 2000	M. A. Sovada and R. J. Greenwood; also reported on Jamestown Christmas Bird Count during Count week (Randall 2000)	Nonbreeding	one
128.	Fargo, Cass County	9 November 2000	C. Norheim	Nonbreeding	one

[a]Observations between 15 April and 31 August were considered breeding-season records, and observations between 1 September and 14 April were considered nonbreeding-season records.

Diets of Northern Flying Squirrels, *Glaucomys sabrinus*, in Southeast Alaska

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Sanjay Pyare, Winston P. Smith, Jeffrey V. Nicholls, and Joseph A. Cook. 2002. Diets of Northern Flying Squirrels, *Glaucomys sabrinus*, in southeast Alaska. Canadian Field-Naturalist 116(1): 98–103.

We examined the diet of the Northern Flying Squirrel (*Glaucomys sabrinus*) during summer and autumn seasons in temperate rain-forest habitat of Southeast Alaska, a region in which the ecology of this species is poorly understood. Truffles, a food item that is commonly consumed by squirrels during snow-free periods outside of Alaska, were present less frequently in squirrel feces than two other food items, epigeous fungi and vegetation, although no food item dominated fecal composition. Truffles were less frequent in fecal samples from mixed-conifer muskeg habitats than from old-growth forest habitats. Overall, we found that squirrels consumed a total of five truffle genera; *Elaphomyces* and *Hymenogaster* being the most common. Compared to populations in the western contiguous United States, squirrel populations in Southeast Alaska consumed truffles less frequently and consumed a smaller total number of truffle genera. In addition, samples from individual squirrels in Alaska tended to contain fewer genera than samples from the contiguous United States. Finally, squirrels in Alaska consumed other food items such as vascular vegetation, lichens, and mushrooms more frequently than squirrels in other geographic areas. These patterns suggest that the association between flying squirrels and truffles may be relatively weaker in Southeast Alaska than has been documented elsewhere. Consequently, additional information on life history and ecology of flying squirrels is warranted before forest management guidelines can be developed.

Key Words: Alaska, diet, lichens, mycophagy, Northern Flying Squirrels, old-growth, Pacific Northwest, truffles

Northern Flying Squirrels (*Glaucomys sabrinus*) are mycophagous and frequently feed on the fruiting bodies of hypogeous fungi (i.e., truffles) in coniferous forests of western North America (Carey et al. 2000; Colgan et al. 1997; Hall 1991; Maser et al. 1985; Maser et al. 1986; Maser and Maser 1988; Pyare and Longland 2001; Rosentreter et al. 1997; Waters and Zabel 1995). Because spores of these fungi are mycorrhizal and remain viable after passage through small mammal digestive tracts, flying squirrels are thought to play an important ecological role by dispersing these spores (Cazares and Trappe 1990; Cork and Kenagy 1989; Kotter and Farentinos 1984; Li et al. 1986; Maser and Maser 1988).

During winter, truffles are uncommon food items for flying squirrels because truffles are less abundant and/or snow cover may limit access to these below-ground fungi. Thus, alternative and readily available food items, such as lichens, are predominant winter food items for flying squirrels. During snow-free periods, however, such as in summer and autumn, flying squirrels are thought to specialize on truffles because flying-squirrel stomachs and feces generally contain a diverse array of truffle genera. Furthermore, squirrels exhibit preferences for truffles over other food items (Zabel and Waters 1997). For the most part, however, our knowledge about these squirrels is restricted to geographic areas where these fungi are abundant and where fungal composition is relatively well documented, particularly in southern regions of the Pacific Northwest, such as in northern California, Oregon, and Washington, U.S.A. (Carey et al. 2000; Colgan et al. 1997; Hall 1991; Maser et al. 1985; Maser et al. 1986; Maser and Maser 1988; Pyare and Longland 2001; Waters and Zabel 1995). In contrast, in northern regions of the Pacific Northwest, such as Southeast Alaska and adjacent British Columbia, little is known about the ecology and food habits of flying squirrels, nor is much known about the distribution of truffles. This is true despite that coastal and interior forests of this region provide extensive habitat for flying squirrels, and provide an abundance of conifers that potentially serve as ectomycorrhizal hosts for truffle fungi. In general, however, it is thought that truffles are relatively uncommon in northern forests possibly because climatic conditions may be too extreme and/or this region may simply represent the northern limits of truffle distribution for some species (E. Cazares, personal communication). Thus, even during snow-free periods, truffles may be less common in this region, and consequently, flying squirrels may be more likely to exhibit generalist-type feeding behavior there (Thysell et a. 1997).

Basic information about squirrel ecology and food habits in this region would have practical merit for contemporary objectives regarding the conservation

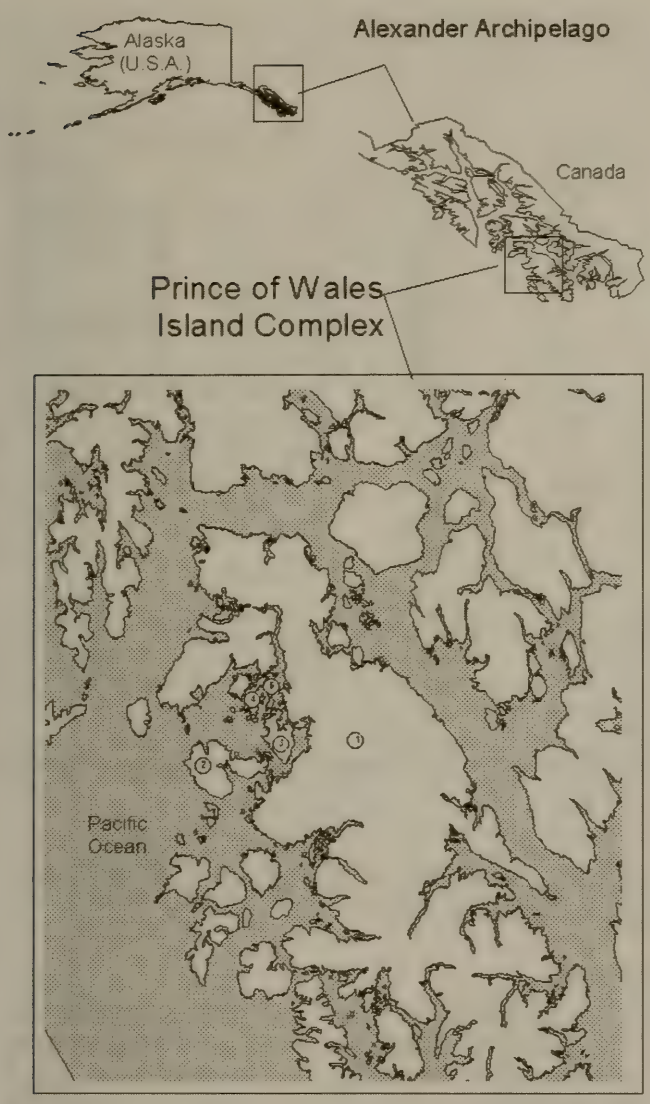

FIGURE 1. Location of study area (Prince of Wales Island complex) in the southern Alexander Archipelago of Southeast Alaska, U.S.A. Numbered locations are as follows: (1) Prince of Wales Island, (2) Heceta Island, (3) El Capitain Island, (4) Tuxekan Island, and (5) North Island.

of the flying squirrel. In addition, an endemic subspecies, the Prince of Wales Northern Flying Squirrel (*G. s. griseifrons*), is found in Southeast Alaska (Demboski et al. 1998; McDonald and Cook 1996). Thus, to provide a more comprehensive understanding of flying-squirrel ecology, we evaluated diet patterns of flying squirrels in temperate rainforest habitats of Southeast Alaska during snow-free periods and compared these patterns to those in the western contiguous United States.

Methods and Materials

We conducted microhistological analyses of flying-squirrel feces collected from a total of 13 forest stands in the Prince of Wales Island complex in the southern Alexander Archipelago of Alaska (Figure 1). These coastal study sites ranged from 200–800 m in elevation. Ten stands consisted of old-growth (unlogged) forest habitat, six of which were on Prince of Wales Island (stands separated by > 5 km): Dargun Point (55°54′44″ N, 133°15′36″ W), Honker 1 (55°20′48″ N, 132°50′08″ W), Honker 2 (55°21′02″ N, 132°50′36), Honker 3 (55°19′54″ N, 132°49′37″ W), Naukati Bay (55°51′25″ N, 133°10′02″ W) and Tuxekan Village (55°54′06″ N, 133°14′55″ W). An additional four old-growth stands were on El Capitan Island (55°55′59″ N, 133°18′33″ W), Heceta Island (55°46′00″N, 133°27′00″W), North Island (55°57′00″N, 133°19′00″W), and Tuxekan Island (55°51′11″N, 133°13′39″W). Finally, three stands consisting of mixed-conifer muskeg habitat were on Prince of Wales Island (stands separated > 5 km): Ball's Lake (55°43′00″N, 132°49′00″W), Control Lake 1 (55°43′48″N, 132°48′54″W), and Control Lake 2 (55°43′24″, 13249′39″W).

Old-growth habitat included Sitka Spruce (*Picea sitchensis*), Western Hemlock (*Tsuga heterophylla*) and Red (*Thuja plicata*) and Yellow cedar (*Chamaecyparis nootkatensis*). Large trees, downed and decaying wood, snags and small gaps created by individual blow-downs all were key components of this habitat. Dense patches of Blueberry (*Vaccinium* spp.) dominated the understory. In contrast, mixed-conifer muskeg habitat exhibited poor drainage, shallow organic soils, and only patches of mixed conifer vegetation that occurred on gently sloping lowlands and floodplains. Conifer vegetation included Yellow Cedar, Red Cedar, Western Hemlock, Mountain Hemlock (*T. mertensiana*), Shore Pine (*Pinus contorta* var. *contorta*), and Sitka Spruce. Understory vegetation varied considerably within this habitat type. Open areas with little overstory consisted of a mixture of herbaceous species (sedges, grasses, Skunk Cabbage [*Lysichitum americanum*]) and Labrador Tea (*Ledum glandulosum*), whereas Blueberry dominated areas with well-developed overstories. Because muskegs are a previously undocumented habitat for Northern Flying Squirrels, we treated data from these stands separately.

We collected fecal samples from flying squirrels in these habitats only during snow-free periods; i.e., when truffles were most likely to be available and/or snow could not preclude access to truffles. On three of the old-growth sites (Honker 1-3) and all three of the muskeg sites, fecal samples were collected from the anus of individually-marked squirrels that were live-trapped in Tomahawk live-traps during autumn (September-October) of 1999 and 2000. No more than one sample was collected from each individual. We did not collect samples that appeared to consist of bait (a peanut butter-rolled oats mixture). For the remaining seven old-growth sites, feces were collected from the digestive tract of museum specimens (University of Alaska Museum, Fairbanks, Alaska). These samples were originally collected during summer (June-July) and autumn 1999.

TABLE 1. Prevalence of different food items in fecal samples collected from flying squirrels in old-growth stands (n = 10) and muskeg stands (3) in Southeast Alaska. Truffle genera found in each stand are shown at right.

		% Occurrence					
	N	Truffles	Lichen	Vegetation	Mushrooms	Insect	Truffle Genera Present
Old Growth Stand							
Honker 1	34	50	50	50	59	12	*Elaphomyces, Hymenogaster*
Honker 2	14	50	20	23	30	0	*Sclerogaster*
Honker 3	21	100	20	56	20	0	*Elaphomyces*
Dargan Point	6	50	12	50	0	0	*Hymenogaster*
Naukati	5	64	20	75	48	4	*Elaphomyces, Hymenogaster*
Tuxekan Village	10	20	64	24	40	0	*Elaphomyces*
Heceta Island	17	40	10	64	23	12	*Elaphomyces, Hymenogaster*
Tuxekan Island	26	36	36	60	24	12	*Elaphomyces*
North Island	3	12	30	84	33	4	*Elaphomyces*
El Capitan Island	14	82	8	56	84	0	*Hymenogaster*
	$\bar{x}$	50.4	27	55.2	36.1	4.4	
	s.d.	26.8	18.4	20.1	23.3	4.6	
Muskeg Stands							
Ball's Lake 1	4	4	20	60	50	0	*Elaphomyces*
Control Lake 1	5	12	40	28	40	0	*Elaphomyces*
Control Lake 2	8	40	0	50	88	0	*Elaphomyces*
	$\bar{x}$	18.7	20	46	59.3	0.0	
	s.d.	15.5	16.3	12.5	21.6	0.0	

All samples were stored separately in glass vials with 70% ethanol. For analysis, small portions of each sample were mixed with 3ml of distilled H_20, and mixed vigorously together to achieve a homogeneous solution. A small drop of the solution was mixed with a drop of Melzer's reagent and placed on a slide, covered with a 18 mm circular slide cover, and observed using bright-field microscopy at 40×. We identified the following different food items in 25 randomly selected field-of-views: the spores of hypogeous fungi and epigeous fungi, algal cells from lichen, and remains of vascular vegetation and insects. Spores of hypogeous fungi were further identified to genus using a spore key (Castellano et al. 1989).

Results

We analyzed a total of 151 fecal samples from old-growth forest sites, and 17 samples from muskeg sites. Among old-growth samples, vascular vegetation was the most frequent food item ($\bar{x} \pm$ se = 55 ± 6.4%), while truffle spores were second most frequent (50 ± 8.5%) (Table 1). In contrast, among muskeg samples, both epigeous fungi and vegetation items were more frequent (59 ± 12.5% and 46 ± 7.2%, respectively) than truffles (19 ± 8.9%).

TABLE 2. Truffle-consumption patterns of various flying-squirrel populations in western North America. All data were collected in mature conifer-forest habitats. Seasons correspond to the following months: Spring (March-May), Summer (June-August), Autumn (September-November), and Winter (December-February).

		% Occurrence By Season			
Location and Source	N	Spring	Summer	Autumn	Winter
Nevada County, California: Hall 1991	107	92	92	81	81
Lake Tahoe Basin, California: Pyare and Longland 2001	93	-	100	100	-
Lassen County, California: McKeever 1960	24	83	100	100	56
Plumas County, California: Waters and Zabel 1995	88	-	100	-	-
Douglas County, Oregon: Maser et al. 1986	162	97	93	99	98
Douglas and Coos County, Oregon: Carey et al. 1999	158	75	-	-	-
Lane and Linn County, Oregon: Maser et al. 1985	28	-	-	100	-
Blue Mountain Province, Oregon: Maser et al. 1985	63	-	-	100	-
Watson Falls, Oregon: Cazares et al. 1999	12	-	94	100	-
Payette National Forest, Idaho: Rosentreter et al. 1997	200	77	78	-	77
Thurston County, Washington: Colgan et al. 1997	12	-	-	-	85
Southeast Alaska (this study)	151	-	50	50	-

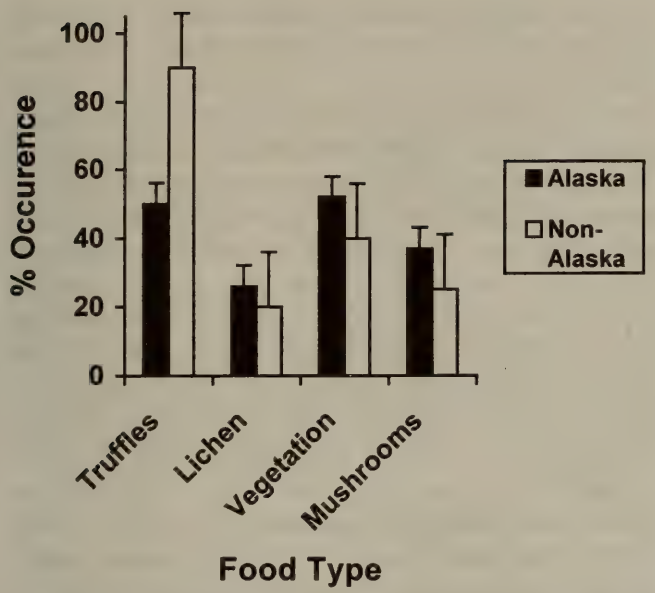

FIGURE 2. Comparison of food-item occurrence in pooled samples between southeast Alaska (n = 10 stands) and outside Alaska (9). Insect frequencies were not reported in most studies and therefore left out of this comparison. All samples were collected in mature conifer-forest habitat during snow-free periods. Bars represent standard error. Non-Alaska data from: Cazares et al. 1999; Hall 1991; Maser et al. 1985; Maser et al. 1986; McKeever 1960; Pyare and Longland 2001; Rosentreter et al. 1997; and Waters and Zabel 1995.

The frequency of lichen in samples was roughly similar between muskeg and old-growth sites (20 ± 9.4% and 27 ± 5.8%, respectively). Five truffle genera were present in old-growth samples. *Elaphomyces* was the only truffle genus present in muskeg samples.

Examination of spring and autumn fecal-analysis data from 11 other forest sites throughout the western United States revealed that overall, the frequency of truffles in fecal samples from southeast Alaska was comparatively low (Table 2; Figure 2). In contrast, the frequencies of lichens, vascular plants, and epigeous fungi were higher in Southeast Alaska than in the contiguous western United States, although these differences were not significant (Figure 2).

Although sample size had a strong influence on the number of truffle genera present in samples collected throughout the western contiguous United States (Figure 3), Southeast Alaska appears to be atypical and does not fit this general correlation. Taxonomic richness of Alaska diets was much lower than otherwise would have been predicted (roughly 22 genera) for the observed Alaska sample size (n = 151; old-growth habitat only). On average, individual squirrel samples from Alaska contained fewer genera than samples from California and Oregon (Figure 4).

Discussion

Although flying squirrels are mycophagous throughout their range, dietary patterns of populations in Southeast Alaska appeared to differ from those in the western contiguous United States during snow-free periods. Compared to their southern counterparts, at the population level, squirrels in Southeast Alaska consumed truffles less frequently and consumed a smaller total number of truffle genera. Furthermore, individual squirrel samples from Alaska contained fewer genera than southern fecal samples. These patterns suggest that flying squirrels may be less dependent on truffles in Southeast Alaska, even during seasons when potential availability is greatest. This is consistent with other studies that have shown that the species may in some instances exhibit generalist-type feeding behavior. For example, Thysell et al. (1997) observed wild squirrels feeding on other types of highly digestible food items such as seeds and berries, and consequently concluded that previous studies involving fecal-analyses have typically underestimated the importance of such food items. More recently, Claridge et al. (1999) concluded that hypogeous fungi were of moderate nutritional value to captive flying squirrels, which failed to gain body mass when fed solely the common fungal sporocarp *Rhizopogon vinicolor*. Additional support for the idea that flying squirrels may in some part of their range be only marginally dependent on truffles comes from the southern Appalachian Mountains, where truffle abundance is relatively low and only a few common truffle genera are found in fecal samples (Loeb et al. 2000; Weigl et al. 1992).

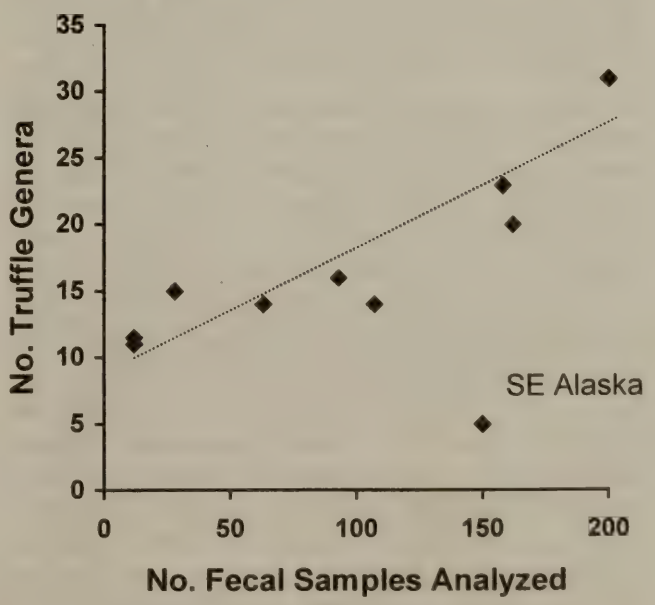

FIGURE 3. Relationship between sample size and total number of truffle genera detected in fecal samples of flying-squirrel populations in western North America (r = 0.90 not including Alaska data). Non-Alaska data from: Carey et al. 1999; Cazares et al. 1999; Colgan et al. 1997; Hall 1991; Maser et al. 1985; Maser et al. 1986; Pyare and Longland 2001; and Rosentreter et al. 1997.

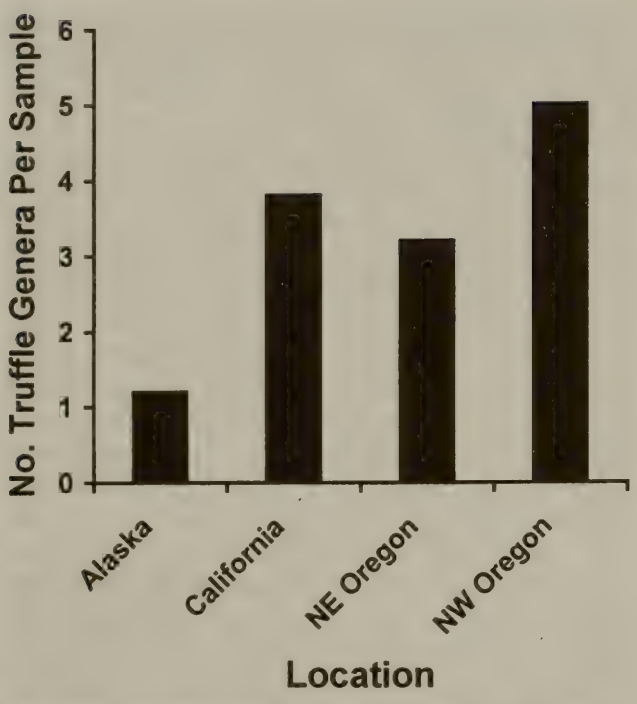

FIGURE 4. Comparison of the mean number of truffle genera per diet sample (i.e. per individual) among four flying-squirrel populations. All data were collected during snow-free periods in mature conifer-forest habitat. Sample sizes and data sources are as follows: Alaska (this study, n = 151); California (Pyare and Longland 2001, 93); NE Oregon (Maser et al. 1985, 63); and NW Oregon (Maser et al. 1985, 28).

Although we did not assay truffle abundance at these study sites, and virtually nothing is known about truffle distribution in Southeast Alaska, the simplest explanation for the disparity in squirrel diets between Southeast Alaska and elsewhere may be due to low truffle availability. Alternatively, snow cover could not have been a factor for the relatively low consumption rates of truffles observed in our study. Nor is it likely that the disparity is explained by differences in food preferences, although we cannot exclude this as a possibility. We never encountered truffles at these study sites, nor did we ever witness mycophagous animal diggings, clues that both scientists and hobbyists commonly use to locate these subterranean fruiting bodies (Waters and Zabel 1995). In contrast, S. P. frequently observed evidence of the association between these animal diggings and truffles in mixed-conifer forest of the Sierra Nevada Range, California. In samples from both old-growth and muskeg habitats in Alaska, the preponderance of *Elaphomyces* spp. further suggests that fungal diversity may be limited perhaps due to adverse climatic conditions of this cool, extremely wet region. *Elaphomyces* spp. have a relatively thick (0.5 cm) outer peridium and are thought of as being among the hardiest of hypogeous fruiting bodies. We are particularly skeptical that truffles fruit to any significant degree in the more open areas of muskeg habitats, the soil of which is often poorly drained and flooded.

The frequency of lichen, vegetation, and mushrooms were all higher in Southeast Alaska samples than samples from elsewhere, although differences were not significant. These other food items may be relatively more important than our simple fecal pellet analysis revealed; volume estimates of stomach contents would certainly have provided a better understanding of ingestion rates of different food items. Of particular relevance to flying squirrels in this region may be the abundance of arboreal lichens, which achieve high biomass and diversity. In particular, *Bryoria* spp. and *Usnea* spp. are known to be consumed by flying squirrels (Rosentreter et al. 1997; Zabel and Waters 1997) and appear to be preferred over other lichens by captive animals (S. Pyare, unpublished data). We commonly observed both of these lichens in these old-growth forest and muskeg habitats during our three-year study of flying squirrels in Alaska.

Conservation and management measures for flying squirrels have conventionally emphasized the underlying importance of hypogeous fungi (Loeb et al. 2000; Maser and Maser 1988; Zabel and Waters 1997). Management plans in Southeast Alaska and in other northern regions, such as coastal and interior British Columbia, however, may further need to recognize the complete array of food items consumed by these northern populations. For instance, in the western contiguous United States, among studies of the impact of disturbances, such as fire, clear cutting, and selective harvesting, on flying squirrel populations, there have typically been concomitant efforts to assay the impacts on truffle abundance or diversity, while the impacts of disturbance on other food types have not been evaluated (Amaranthus et al. 1994; Carey et al. 2000; Cazares et al. 1999; Colgan 1997; Waters et al. 1994; Waters and Zabel 1995). Management strategies in northern regions, however, may require a more pluralistic understanding of disturbance impacts on lichens, vascular plants, and mushrooms, as well as belowground fungi. Furthermore, because patterns of foraging, movement, and habitat use differ as a consequence of these different feeding habits, management strategies may require additional efforts to understand the unique ecological niche flying squirrels occupy in this particular region.

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Nesting Activities of an Eastern Spiny Softshell Turtle, *Apalone spinifera*

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Une tortue-molle à épines a été suivi étroitement durant la période de ponte de 1998. Cette tortue a démontré un patron quotidien d'activité régulier avant la ponte. Elle consacrait ses matinées à s'exposer au soleil et à se déplacer dans un secteur restreint, ses après-midi à se déplacer sur des distances de 2 à 3 km, pour finalement s'arrêter en fin d'après-midi alors que durant la soirée, elle semblait être à la recherche d'un endroit propice pour déposer ses œufs. Cette tortue-molle à épines a démontré la capacité de se déplacer à contre courant sur une distance de plus de 7 km, en trois jours, pour aller pondre.

An Eastern Spiny Softshell Turtle was closely followed during the 1998 nesting season. It showed a rather consistent daily pattern of activity. The morning was spent basking and moving around in a small area, large movements (2-3 km) were made during the afternoon and the turtle would stop for the evening, acting like it was searching for a suitable nesting site. This softshell turtle moved 7 km upstream in three days for nesting.

Key Words : Eastern Spiny Softshell Turtle, *Apalone spinifera*, nesting, movement, activity, Québec, Canada.

The information reported here was collected in the course of a larger study designed to help the conservation of a unique Québec population of Eastern Spiny Softshell Turtle (*Apalone spinifera)* (Galois, 1999*). Attempts were made to follow three females to their nesting sites, but we were successful with only one. This adult female (535) was captured 18 June 1997 in Rivière aux Brochets (Figure 1), a tributary of Lake Champlain (73°13′W, 45°04′N) and equipped with a radio transmitter (frequency 155.535; Holohil System Ltd, Ottawa, Canada) provided with a mortality option that produces a double bip when the turtle remains still for more than four hours. The softshell spent the winter of 1998 in the Missisquoi River near Swanton, Vermont, U.S.A. (73°13′W, 44°58′N), moved north across Lake Champlain during the first half of May, and up in the Rivière aux Brochets, where it spent the following three weeks in the vicinity of a small island, more than 25 km away from its wintering area. We followed 535 for most of the daylight hours during the few days before nesting and the day after nesting in June 1998. Although nesting activities had been described before (Eigenman 1896; Newman 1906; Evermann and Clark 1920; Minton 1972; Ernst et al. 1994), few individuals were involved in those observations, and daily activities shortly before and after ovoposition has not been reported previously.

9 June, mostly sunny, 26°C

At our arrival (10:15), 535 was basking on the sunny side of the river, approximately 20 cm from water, with two other softshell females basking a few meters away. They started moving at around 11:30, going in and out of the water. By 13:30, 535 had left the area and moved upstream throughout the afternoon. At 18:00, after swimming about 2 km, it stopped and remained in the area until we left at 20:00.

10 June, sunny, 22°C

When we arrived at 5:30, 535 was in the same area as the previous evening. The signal became double at 9:30, indicating that the turtle had not moved for the last 4 hours. At 9:30, we spotted 535 basking on a stone in the river, approximately 5 m from the shore. It entered the water at 10:30 but remained in the area. By noon, it had started moving upstream. The river was about 30 cm deep and 30 m wide, and steep banks allowed us to often have a good look in the water. On many occasions we could see 535 passing by. It swam vigorously, its neck fully extended, pointing its nose out of the water every 5 to 10 m and sometimes stopping in this position for a few seconds. The softshell kept this pace for the whole afternoon. At 17:00, it stopped next to a gravel bar 5 m long but only 10 to 20 cm above the

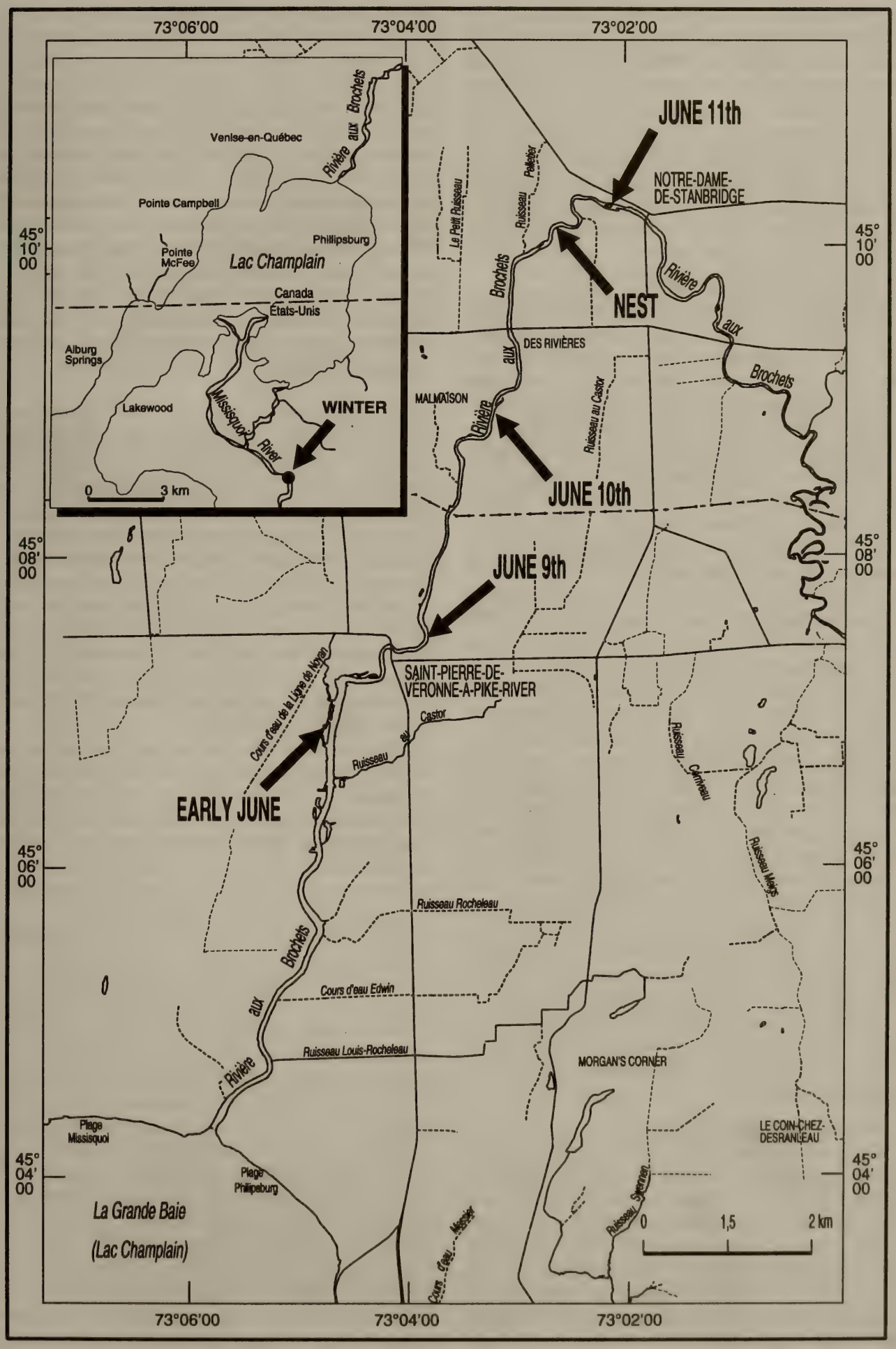

FIGURE 1. Movements of a female Eastern Spiny Softshell Turtle during the nesting season.

water level, almost 3 km from its point of departure at noon. The softshell came out of the water at 17:30, moving around on the gravel bar and rubbing its chin on the substrate every now and then. It re-entered the water 10 minutes later, but climbed back on it at 19:50, departing about 20 seconds later when disturbed by a man passing on the road 10 m away. At 20:10, it climbed once more on the gravel bar, but was disturbed a second time by human activities. The softshell was still in the area when we left at 21:00.

11 June, mostly sunny, 22°C

We returned to the area at 6:00. Although not visible, 535 was still around. At 8:30, the signal became double and remained so until 10:15. For the next hour, the turtle seemed to be moving around, but staying in the area. At 11:15, 535 walked on the gravel bar in spite of the presence of six ducks. Again, the softshell seemed to be rubbing its chin on the ground. By 11:30, it was back in the water and swam intensively upstream throughout the afternoon. It climbed on the sunny shoreline of the river at 15:50, approximately 2.5 km away from its daily departure point. It moved in and out of the water on a 30 m stretch of the river, next to a sharp curve. At 16:05, 535 walked on land for the sixth time, at the other end of the curve, about a hundred meters upstream from where it had first gone on land, but only 20–30 m in straight line through forest. The softshell started the excavation at 16:15 at the edge of the vegetation, into gravel and flat pebbles ranging in size from 1 to 10 cm long. The first part of the digging motion was slow, but it ended vigorously and pebbles were thrown up to 2 m away. The excavation stopped at 16:35. After a few minutes without moving (probably laying), the turtle started filling the hole at 16:45. The softshell ran back into the water at 16:49, 44 minutes after coming out of the water. The nest was excavated 2 m from the water and approximately 1 m above the water level, in full late afternoon sunshine (northwestern slope). Numerous other signs of nesting activity were present in the vicinity. The softshell immediately started swimming upstream. We observed 535 at 20:00, 1 km upstream from where it nested, about 100 m below a dam in a small village. We left the area for the night.

12 June, partially sunny, 24°C

When we arrived at 6:40, the turtle had moved downstream about 0.5 km from where we last saw it the night before. The signal was double but became single 10 minutes later, indicating that the turtle just started to move after a stop of at least four hours. The radio indicated that the softshell was moving downstream. It swam by its nest at 7:00. A large Snapping Turtle (*Chelydra serpentina*) was digging a few meter from where 535 had excavated its nest the night before. We saw the softshell at 8:40, and then again at 10:15. It was swimming vigorously, in the same way it had been during the few days it spent moving up the river. We stopped tracking the turtle around 11:00 to check the softshell's nest to confirmed that it had really laid eggs. We found eggs exactly where the turtle dug the night before. In order to avoid any disturbance in the incubation process, eggs were covered, without counting them, as soon as we discovered the first egg. We tracked the turtle during the whole afternoon and by 17:30, 535 was back in the area it left 9 June. Travelling downstream, it took the turtle one day to cover the same distance that had required three days moving upstream. Swimming time summed up to 11 hours travelling downstream and 17 hours moving upstream.

Discussion

Most events observed while tracking this softshell turtle are comparable to what other authors have described about *A. spinifera* nesting habits. We were impressed by the last part of the digging strokes, but Minton (1972) also reported that softshells were vigorously throwing the sand several meters away. Newman (1906) reported that nesting process usually lasts about one hour and 535 completed the entire process in 44 minutes. Breckenridge (1960) reports almost exactly the same nesting observations from Minnesota as ours, in terms of date, time, duration and behaviour. According to Newman (1906) nesting can also occur at midday.

What was most notable about our observations was the daily pattern of activity preceding nesting. The day seemed divided into 3 parts. Morning would be spent basking and moving around in one area. Around noon, the turtle would leave the area and spend the whole afternoon swimming vigorously. By the end of the afternoon, the turtle would stop and then seem to be looking around for a suitable nesting spot.

Our observations raised the following questions: Did the turtle choose this specific nesting site because it did not find any other suitable site while travelling or was it going for this exact spot because it knew it from past nesting experiences or because she had hatched there? We know that 535 was in this part of the river during the 1997 nesting season but it was not observed in nesting behaviour. What was the influence of the area's other nests in 535 choice? Smell seemed to have played a significant role in her search. We believe that this is what brought her out of the water the day it nested. She first moved on land at the beginning of a sharp curve probably smelling the nests at the other end of this curve, only a few meter away through forest. As reported by Fletcher (1996*), our observations indicated that *Apalone spinifera* can move considerable distance in a short period of time, exploring different potential nesting sites. This would suggest that confirmation

of the nesting site of any specific turtle can only be achieved through direct observation of the laying process.

Acknowledgment

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Long-distance Movements by Female White-footed Mice, *Peromyscus leucopus*, in Extensive Mixed-wood Forest

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Maier, Thomas J. 2002. Long-distance movements by female White-footed Mice, *Peromyscus leucopus*, in extensive mixed-wood forest. Canadian Field-Naturalist 116(1): 108–111.

Two adult female White-footed Mice (*Peromyscus leucopus*) were recovered 14 730 m and 6840 m from where they were originally captured and tagged in central Massachusetts. Similar combinations of factors throughout an extensive forested landscape, including poor acorn (*Quercus* spp.) crops, high population densities of mice, and the exclusive social behaviour of other female mice, may have been responsible for these long distance movements.

Key Words: White-footed Mouse, *Peromyscus leucopus*, dispersal, distance, mixed-wood forest, movement, *Quercus*, small mammals, social dynamics, Massachusetts.

Movement in space-time remains a little understood process for most organisms (Turchin 1998). Even less understood are long-distance movements (Koenig et al. 1996), such as those made by small mammals dispersing across landscapes (Zollner and Lima 1999; Andrzejewski et al. 2000; Bowman et al. 2001). Nonetheless, even sporadic long-distance movements by small mammals may profoundly affect species' evolution, population dynamics, and community structure (Cockburn 1992; Allen et al. 1993; Berlow 1999). As such, recognition of the spatial scale of such movements and their proximal causes becomes integral to understanding certain wildlife requirements, the effects of habitat perturbation, and possible epidemiological risks (Dickman et al. 1995; Kozakiewicz and Szacki 1995; Calisher et al. 1999). Here I report long-distance movement events by two female White-footed Mice (*Peromyscus leucopus*) in extensive, New England mixed-wood forest, and discuss these movements in relation to the associated environmental conditions.

Observations

One month after capture on a small mammal trapping grid within the Quabbin watershed in central Massachusetts (42°27'13.7"N, 72°21'03.7"W), a tagged White-footed Mouse was recaptured 14 730 m north of the original capture site. The adult female (21.2 g), apparently healthy and not exhibiting any signs of reproductive activity, was ear-tagged with a No. 1 Monel tag (National Band and Tag Co., Newport, Kentucky, USA) on initial capture, 15 October 1998, and subsequently recaptured twice more at the same site. Approximately 4 weeks later, this mouse was trapped within a residence. Its identity was verified based upon gender and the fact that no other small mammal researchers working in the area were using tag numbers in this sequence; a necropsy was not performed. A second tagged White-footed Mouse was trapped at another residence 750 m northeast of the same Quabbin trapping grid during the same time period. This mouse was disposed of before verification of its identity. In mid-April 1993, the desiccated remains of another tagged White-footed Mouse were found outside a third residence 6840 m north of its original capture site. This adult female, when captured on another small mammal trapping grid within the Quabbin watershed (42°26'50.9"N, 72°19'29.8"W) on 12 August 1992 (its only capture), appeared healthy and did not exhibit any signs of reproductive activity. Its identity was verified as described above.

Both trapping grids on which these mice were initially captured were located within a fenced portion of the Quabbin watershed, with vehicle entry restricted by locked gates (this property is managed by the Metropolitan District Commission to provide water for the Boston municipal area). The landscape between the initial capture and final recovery sites consisted of contiguous, closed-canopy mixed-wood forest of a predominately Red Oak (*Quercus rubra*)-White Pine (*Pinus strobus*)-Red Maple (*Acer rubrum*) forest cover type (Eyre 1980) with scattered residential and agricultural openings. For the two mice traveling the furthest, potential travel routes were bisected by a minimum of six light-duty forest roads, three small streams, a two-lane primary highway, and a powerline right-of-way. Geomorphological features run mostly north-south and range in elevation from 200–380 m. Distances, unless otherwise specified, were measured using a Rockwell PLGR+96 Global Positioning System receiver with a minimum horizontal accuracy of 10 m, and analyzed using ARC/INFO on a Sun SPARC station.

Other environmental conditions characterizing the 1998 period included high White-footed Mouse den-

sity at the Quabbin trapping site (136/ha) and adjacent sites (58–89/ha) (T. Maier, unpublished data). Few mice were actively breeding at this time, but large numbers of juveniles were observed (T. Maier, unpublished data). In comparison, historic densities for these mice for similar local habitat at the same time of year have ranged from 1 to 126/ha, with a mean density of 27.8/ha, SD = 30.6 (9 years data; W. Healy, USDA Forest Service, personal communication). Area acorn (*Quercus* spp.) crops yielded > 75% less than the previous year, with virtually the entire 1998 crop consumed by Acorn Weevil (*Curculio* spp.) larvae (R. Field, USGS Biological Resources, personal communication; W. Healy, personal communication). Local climatological statistics for a 44-day period in 1998 encompassing the potential travel of mice were a mean maximum temperature of 10.5° C; mean minimum temperature of -0.9° C; mean temperature of 4.9° C, and total precipitation of 24.3 mm, all as rain from five precipitation events (NWS*). Environmental conditions characterizing the 1992 period beginning in August similarly included high White-footed Mouse density at the Quabbin trapping site (81/ha) and adjacent sites (40–126/ha), and the absence of an acorn crop throughout the area, with mice populations dramatically declining by October of the same year (Elkinton et al. 1996). All population density estimates were generated using program CAPTURE (Otis et al. 1978; White et al. 1982).

Discussion

Although the distance covered by the furthest traveling White-footed Mouse reported here supersedes previous reports of long-distance movement by either homing or non-homing individuals of this species (2 km, Wegner and Henein 1991), the genus *Peromyscus* (3.2 km, Murie and Murie 1931), and the family Muridae (14 km, Dickman et al. 1995), travel over the 14.7 km tract during the period from initial to final capture was well within the potential capability of *Peromyscus* mice. Murie and Murie (1931) reported a Deer Mouse (*Peromyscus maniculatus*) returning over 3 km to its capture site in 2 days. Similarly, Calisher et al. (1999) reported an adult Deer Mouse homing 1200 m within 24 hrs. Dice and Hoslett (1950), comparing the performances of seven species of *Peromyscus* on activity wheels, reported a maximum 24-hr record the equivalent of 37 km of travel by an individual White-footed Mouse. Besides possessing the stamina to travel great distances in short amounts of time, these mice have additionally been observed to surmount various obstacles to travel (Sheppe 1965; Teferi and Millar 1993; Calisher et al. 1999) similar to those found in this observation. The possibility that these mice may have been transported via human conveyance cannot be totally discounted, but this seems unlikely given that the mice were initially captured within a restricted area behind locked gates. Additionally, personal interviews with the residents who collected these mice revealed that their closest physical proximity consisted of one or two instances of a briefly parked vehicle (< 4 h during daylight) approximately 2.5 km from where the 1998 mice were initially captured.

Most dispersal (*sensu* Lidicker and Stenseth 1992) by small rodent species has been observed to occur over short distances (McShea and Madison 1992; but see Koenig et al. 1996), with longest distances associated with travel by males for most species. What factors may have contributed to long-distance travel by female White-footed Mice? First, the contiguous forest was likely advantageous to long-distance movements, compared to a more fragmented landscape (Yahner 1983; Krohne and Hoch 1999). Second, food deprivation has resulted in increased activity by *Peromyscus* (Falls 1968 and references therein). Although Acorn Weevil larvae infestations may represent a significant dietary supplement, they are unsuitable as a primary energy source compared to sound acorns (Semel and Andersen 1988; Steele et al. 1996) from autumn through spring (Kirkpatrick and Pekins 2002). Third, an increase in population density has been observed to increase the number of dispersing *Peromyscus* mice (Fairbairn 1978; Krohne et al. 1984). Fourth, resident *P. leucopus* females may especially exclude conspecific female immigrants when resources decline (Metzgar 1971; Wolff 1989). Together, these factors suggest that the combination of high mouse density and low food supply throughout a large extensively-forested area may have created a social environment that inhibited local immigration, as posited by Stickel (1968) and Anderson (1989), thereby increasing the probability of long-distance travel by emigrating female mice. Other reports of long-distance movement by small mammals through large areas of continuous habitat have suggested high population densities as the incentive (Clark et al.1988; Bowman et al. 1999). Nevertheless, as observed by Fairbairn (1978), such movement is not likely a simple function of density or its fluctuation, but rather relates to individual behaviour within a social structure along with changing resource patterns.

Proximal factors leading to long-range movements are difficult to elucidate; this may be due to the interaction of contributing factors, and perhaps, in part, because so few observations of such movements exist. Various studies have attempted to assess the spatial mobility of small mammals using arrays of traps (Krohne et al. 1984; Liro and Szacki 1994; Dickman et al. 1995; Andrzejewski et al. 2000; Bowman et al. 2001); yet, due to logistical and methodological constraints, the probability of detection of marked animals may be expected to decline exponentially with distance, resulting in the significant underestimation of long-distance movements (Koenig et al. 1996; Turchin 1998). The long-distance movements report-

ed here may eventually prove more common than previously thought, requiring those studies modeling the spatial distribution of similar small mammals to adopt a new metric.

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Recent Trends in Stem Numbers in Goldenseal, *Hydrastis canadensis*, Populations at the Northern Limit of its Range

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Sinclair, Adrianne, and Paul M. Catling. 2002. Recent trends in stem numbers in Goldenseal, *Hydrastis canadensis*, populations at the northern limit of its range. Canadian Field-Naturalist 116(1): 112–115.

A 15% increase in stem number occurred in 14 natural Ontario Goldenseal populations surveyed between 1998 and 2000, based on maps of stems in 1m^2 quadrats. Increase occurred in 10 of the 14 populations and was significant. The increase mostly involved small stems, but neither seedlings nor very small plants were observed suggesting that stem increase was largely due to vegetative reproduction by rhizomes and/or root tips. These data correspond to expectation since populations have not expanded rapidly nor spread substantially over the past few decades, but rather appear to have expanded slightly and slowly. Corresponding to earlier speculation, evidence is accumulating to suggest that substantial spreading and large population increases may be dependent on specific kinds and levels of disturbance some of which are no longer prevalent or frequent.

Key Words: Goldenseal, *Hydrastis canadensis*, rare plant, medicinal plant, population trends, demography, population growth rate, population structure, management, monitoring, southwestern Ontario

The top-selling and increasingly popular (Small and Catling 1999; Foster 2000*) deciduous woodland plant, Goldenseal (*Hydrastis canadensis* L.) was recently re-evaluated as threatened in Canada (COSEWIC 2000*) due to few scattered populations, habitat loss, and potential threat of overcollection for the medicinal plant market (White 1991*; Sinclair and Catling 2000a). The 20 populations in Canada occur in southwestern Ontario at the northern limit of its native range, which extends from southern Wisconsin to southern Vermont and south to Arkansas and northern Georgia (Sinclair and Catling 2000a). The perennial rhizomes of Goldenseal, which produce an annual stem each year and enable vegetative reproduction, are collected for the medicinal plant market. The market demand for Goldenseal has been largely met by harvest of wild populations in the United States (Foster 1991; Small and Catling 1999; USFWS 1997*), which are now considered endangered, critically imperilled, imperilled, rare, or uncommon, depending on the State (USFWS 1997*). Apart from anecdotal observations, information on growth trends in Goldenseal populations is lacking for all parts of its range. Such information is essential for the development of effective conservation strategies and monitoring programs, and the need for it has been emphasized in the most recent review of goldenseal ecology and population biology (Gagnon 1999*). Here we present trends in population structure and growth rate, over two years, from 14 natural Goldenseal populations in southwestern Ontario.

Methods

In May of 1998, a 1m^2 quadrat was placed at the edge of a single colony within each of 14 naturally occurring Goldenseal populations. The 14 populations occur in Lake Erie Lowland Ecoregion 135 and the southwestern portion of adjacent Manitoulin-Lake Simcoe Ecoregion 134 of the Mixedwoods Plains Ecozone (Ecological Stratification Working Group 1995). Site numbers in Figures 2, 3, and 4 correspond to locations (Sinclair and Catling 2000a) on file with the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) [see Sinclair and Catling 2000a and references therein]. Each quadrat was permanently marked with four aluminum pins and a numbered aluminum tag. All stems were mapped within each quadrat according to the following size classes: small (single leaf $\leq$ 5 inches in width); large (single leaf $>$ 5 inches in width); and flowering (two or more leaves). The flowering stems are produced by larger rhizomes which are presumed to be the oldest. The smallest stems are generally associated with small rhizomes or root tips. Presence or absence of seedlings was noted. Due to the clonal nature of the plant, all of the stems may have developed from a single individual. The distinction between ramets and genets was beyond the scope of the present survey. In May of 2000, the 14 quadrats were revisited and remapped according to the same size classes. In July of both years, quadrats were revisited to record fruiting stems. The quadrat maps developed in 2000 were compared to those developed in 1998 to document any change in stem numbers and size classes. Total number of stems, as well as

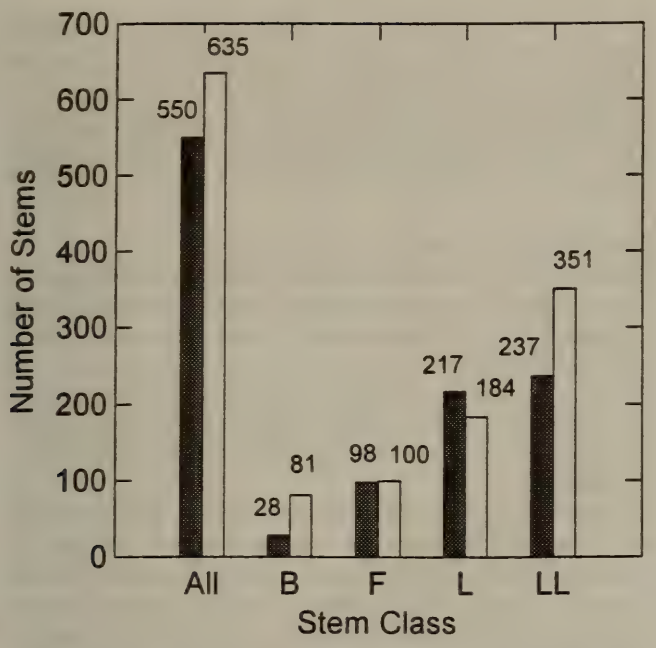

FIGURE 1. Histogram showing overall trend in population structure, from 1998 to 2000, based on a m^2 quadrat sample from each of 14 goldenseal populations in Ontario. B = fruiting, F = flowering, L = large non-flowering, LL = small non-flowering.

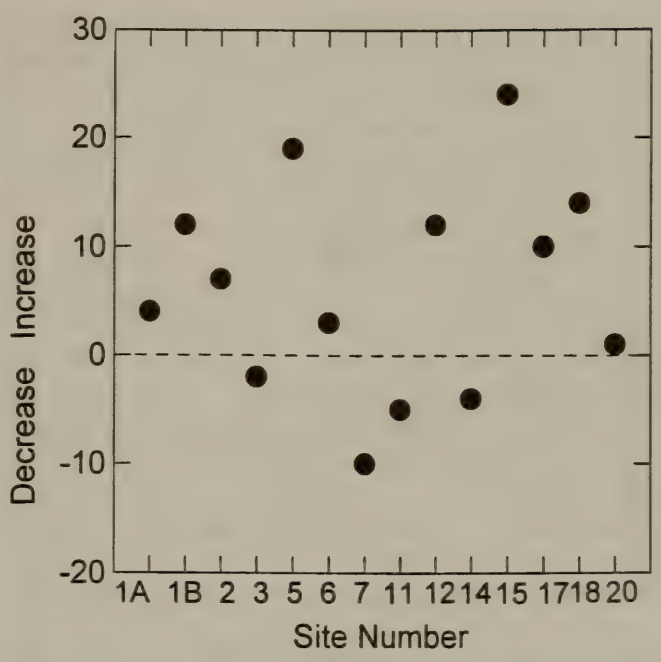

FIGURE 2. Increases or decreases in stem number, from 1998 to 2000, based on a m^2 quadrat sample from each of 14 goldenseal populations in Ontario.

numbers of small, large, flowering, and fruiting stems, over all sites, were compared between the two years using simple t-tests.

Results and Discussion

There was no evidence of harvest, or other recent disturbances (tree removal, trampling, etc.), at any of the 14 populations. Overall (14 quadrat samples combined), between 1998 and 2000, there was a significant increase of 15% ($p = 0.0036$, 550 to 635 stems, Figure 1). Ten out of 14 patches show an increase in the number of stems (Figure 2). The greater number of stems in 2000 is due to a significant increase in the number of small stems ($p = 0.003$, Figures 1 and 3). Almost all patches show an increase in small stems, and the increases are much greater than the losses (Figure 3). No seedlings or very small plants (≤ 1 inch leaf width) were noticed, suggesting that stems developed from roots or rhizomes of existing plants and that effective recruitment by seed was negligible. These data suggest that patches are slowly expanding by vegetative reproduction. Fruiting stems have also increased with marginal significance ($p = 0.045$, Figures 1 and 4). Only two patches show a decrease in the fruiting component (Figure 4). The increase in fruiting stems was not associated with increased flower production: virtually no change occurred in flowering stems (Figure 1). The increased number of fruiting stems in 2000 is therefore a result of a greater proportion of flowering stems producing fruit, which may have been a consequence of the weather. Although reduced herbivory could also be an explanation, there was no evidence for this. No increase in seed production capability actually occurred. Large stems have decreased but the loss is not statistically significant (Figure 1).

These data correspond to expectation since populations have not expanded rapidly nor spread substantially over the past few decades, but rather appear to have expanded slightly and slowly (Sinclair and Catling 2000a). The 15% increase in overall stem production and the increased fruit production were

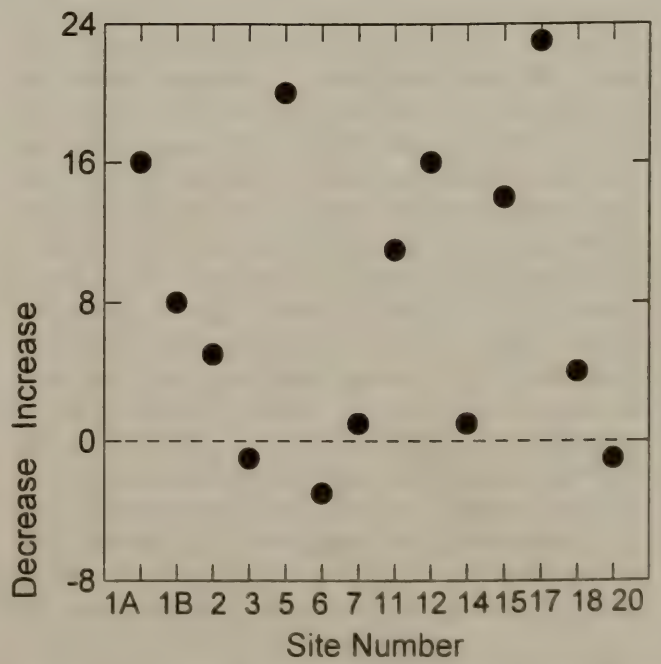

FIGURE 3. Increases or decreases in number of small, non-flowering stems, from 1998 to 2000, based on a m^2 quadrat sample from each of 14 Goldenseal populations in Ontario.

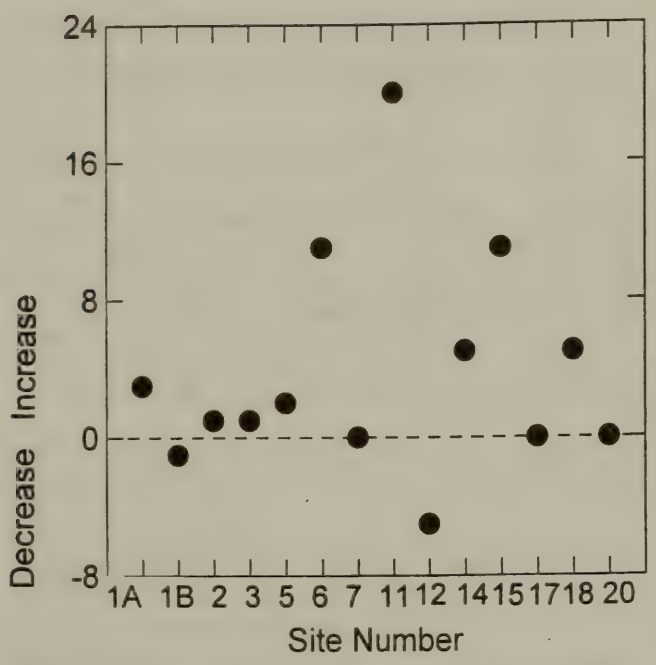

FIGURE 4. Increases or decreases in number of fruiting stems, from 1998 to 2000, based on a m^2 quadrat sample from each of 14 Goldenseal populations in Ontario.

possibly a result of the relatively warmer summers of 1998 and 1999, which are characteristic of the main Goldenseal range further south.

The lack of evidence for reproduction by seed suggests that a limitation must be operating on sexual reproduction other than pollination and dispersal (see Sinclair et al. 2000). The stability of Ontario Goldenseal patches correspond to trends in other woodland perennials, such as American Ginseng (*Panax quinquefolius* L.) and Wild Leek (*Allium tricoccum* Ait.), which are slow-growing with population growth rates near equilibrium (population stability or maintenance, Charron and Gagnon 1991; Nault and Gagnon 1993). Conversely, in disturbed habitats, where more resources such as light and nutrients are made available, plants tend to have highly variable population growth rates which can reach well above equilibrium (e.g., Furbish's Lousewort (*Pedicularis furbishiae* S. Wats.) and Downy Oatgrass (*Danthonia sericea* Nutt.), as noted by (Gagnon 1999). Since occurrences of Goldenseal have been associated with disturbance (Sinclair and Catling 2000b), it seems probable that substantial spread and increase in Goldenseal populations is disturbance-dependent. The results of recently initiated field experiments, along with further population monitoring, will enable a better understanding of disturbance effects and provide useful information for recovery and management.

Acknowledgments

Fieldwork was supported by the Endangered Species Recovery Fund (ESRF) of World Wildlife Fund Canada and the Canadian Wildlife Service of Environment Canada, and also by Agriculture and Agri-food Canada and the University of Ottawa. Keiko Lui, Josh Flanagan, and Bruce Sinclair provided field assistance. Conservation Authorities and private landowners kindly allowed us to work on their properties.

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Addenda

Corrections and additional notes for "Ontario Goldenseal, *Hydrastis canadensis*, populations in relation to habitat size, paths, and woodland edges". *Canadian Field-Naturalist* 114(4): 652–655.

A substantial interest in this earlier article has lead to the following notes. One reader questioned whether or not paths in woodlands represent a random sample of the habitat? In other words paths may follow habitat subunits within woodlands, such as higher ground. Thus certain plant distributions in a forest may be correlated with paths but without the paths themselves being a causal factor. The woodlands containing populations of Goldenseal that we examined were either flat or uniformly and gradually hummocky. The paths, which were associated with the use of tractors or all-terrain vehicles, appeared to be a random sample of the habitat. The paths were not conspicuously associated with openings in the canopy, although some of the edges certainly received more light than the interior. Consequently disturbance apparently benefitting Goldenseal did not appear to be light-dependent, although increased light may contribute to a beneficial effect.

Neither of the following two corrections changes the conclusions of the paper:

(1) In calculating the effect of natural area size, all populations within a natural area should have been pooled. This applies to three cases (a) 11, 12, 13 and 14, (b) 16 and 17, (c) 1A and 1B, all in table 1. Instead of "a marginally significant decrease in number of Goldenseal stems with increasing natural area size", there was no significant relationship between number of Goldenseal stems and natural area size ($P = 0.982$, $R^2 = 0.0$). It is of interest to note here that when 3 large sites with large leverage were removed from the data set, there was still no significant relationship with natural area size.

(2) The figures in the D-value column in Table 1 are incorrect and so is the procedure described at the end of results in the first two sentences of the paragraph beginning "In order to ...". This should read "In order to ... disturbance values were assigned to each site based on a scale of 1–5 (1 = undisturbed, 5 = heavily disturbed). The assessment was based subjectively on a number of factors including gaps in the canopy, evidence of a cutting operation (bulldozing, stumps, log dragging, etc.), trampling and vehicle tracks, and presence of invading alien species and/or native species of more open sites." Since this is actually what was done there is no change to the results or conclusions. The column of D values in Table 1 from top to bottom should be 3, 5, 2, 5, 1, 1, 2, 1, 2, 5, 3, 2, 1, 1, 1, 2, 3, 1, 1, and 5.

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A Comparison of Techniques for Assessing Amphibian Assemblages on Streams in the Western Boreal Forest

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Paszkowski, Cynthia A., Garry Scrimgeour, Beverly A. Gingras, and Sharon Kendall. 2002. A comparison of techniques for assessing amphibian assemblages on streams in the western boreal forest. Canadian Field-Naturalist 116(1): 116–119.

The western boreal forest of Canada is rapidly being altered by agriculture, forestry, and energy extraction. As part of the Alberta Forest Biodiversity Monitoring Program's effort to develop monitoring schemes for biota associated with streams, we compared the performance of four sampling techniques for amphibians (constrained visual searches, call surveys, pitfall traps, and above-ground funnel traps) in June through August along two low gradient streams. Of the four anuran amphibian species that occur in the region, we encountered adults and young-of-the-year of two, Wood Frog (*Rana sylvatica*) and Western Toad (*Bufo boreas*), with the former species dominating our surveys. Given the time and equipment constraints imposed by the monitoring-program protocol, visual surveys proved to be the most effective technique (88.5% of amphibian records) for simply determining the presence of species. Pitfall traps performed better than funnel traps. Call surveys were the least effective technique principally because sampling took place after most breeding was completed.

Key Words: Alberta, biomonitoring, pitfall trap, visual survey, sampling techniques, Western Toad, *Bufo boreas*, Wood Frog, *Rana sylvatica*.

Within the last decade the boreal forest in Alberta, which covers the northern half of the province (Rowe 1972), has become increasingly disturbed and fragmented by agricultural expansion, logging, energy extraction, and road building. The cumulative effects of municipal and industrial activity on boreal ecosystem integrity and biodiversity are receiving increasing attention. The Alberta Forest Biodiversity Monitoring Program (AFBMP) was established in 1996 to identify a suite of quantifiable biological attributes (i.e., variables ranging from the individual to the community-level) to serve as indicators of sustainable forest management and to develop sampling protocols for detecting changes in terrestrial and aquatic biodiversity within Alberta's 500 000 km^2 forested land base (Schneider1997*).

AFBMP is based on a network of 1250 sites located on a systematic grid. Individual sites will be monitored once every 5 years with 250 sites visited annually. Each site will include terrestrial habitat to be sampled for nonvascular and vascular plants, arthropods, birds, and mammals. The terrestrial habitat will be paired with a nearby stream location. Forest streams are sensitive to catchment disturbances and respond quickly to changes in adjacent habitats (Power et al. 1988; Welsh and Ollivier 1998). Because sites are numerous and remote (crews will typically fly in), sampling of all stream biota (benthic algae, macroinvertebrates, fish) and habitat features will be completed by a two-person crew in 2 - 4 days with only 0.5 - 1.5 days allotted to any particular taxonomic group. Sampling will occur in June, July, and August.

Because of the presumed sensitivity of many species to degradation of both terrestrial and aquatic habitats (Green 1997), amphibians would seem a natural group for inclusion in AFBMP surveys. Likewise, the ambitious scope of the program offers a unique opportunity to increase our meager knowledge of the distribution and ecology of the six anuran and two caudate amphibians that occur in Alberta's forests, particularly elucidating their use of streams and adjacent riparian habitat (Russell and Bauer 2000). However, given the time and resource constraints of the proposed survey design and well documented natural fluctuations in amphibian numbers (Semlitsch 2000), two questions emerge: "What sampling techniques perform best?" and "Will survey results support the use of amphibians as environmental indicators by AFBMP or other large-scale monitoring programs?'

To address these questions, our study compared four techniques for sampling amphibians (constrained visual searches, call surveys, pitfall traps, and above-ground funnel traps) along two low gradient streams in the boreal forest of northeastern Alberta. Surveys adopted the previously described constraints on effort, seasonal timing, and equipment prescribed by AFBMP stream protocols.

Materials and Methods

In 1999 amphibian assemblages were sampled along two third-order forest streams, Bear Creek (55°44′55″N, 112°12′16″W) and Crow Creek (55°37′26″N, 112°11′36″W), north of Wandering

River, Alberta. Sites were within the known ranges of four species of amphibians (all anurans) that are widespread in boreal Alberta (Russell and Bauer 2000): Western Toad (*Bufo boreas*), Canadian Toad (*Bufo hemiophrys*), Boreal Chorus Frog. (*Pseudacris maculata*), and Wood Frog (*Rana sylvatica*).

Visual surveys

Amphibians were surveyed three times at each stream: June (14 - 20), July (12 - 16) and August (23 - 27). During a survey period, the two-person team performed low intensity area-constrained visual searches (Crump and Scott 1994) on two dates between 08:00 and 12:00 MDST. Searches were conducted along 200 m long × 1 m wide flagged transects, one on each side of the stream at a distance of 1 - 5 m from the streambed. One person walked slowly searching for animals active on the surface. Animals were captured by hand, identified to species, measured (snout-urostyle length, SUL), weighed, aged based on size and date of capture ("adults" = 1+year old, any individual captured in June or individuals > 27 mm SUL in July-August; young-of-the-year = newly metamorphosed individuals captured in July-August, ≤ 27 mm SUL; based on C. Paszkowski, unpublished data for Wood Frog and Western Toad), then released. Forty-two percent of the individuals observed during surveys escaped capture. These animals were identified to species and assigned an age if possible. The location of each amphibian encountered (captured or observed) was recorded based on markers placed at 50-m intervals along the transect. The total time required to survey a transect ranged from 18 to 60 min. To control for effort, we calculated the total number of animals encountered per hour of searching.

Call surveys

At both sites, we performed call surveys with and without recording devices. Surveys with a "live" listener followed the audio strip technique (Zimmerman 1994). These were performed twice per month (one survey per date), at the same time and on the same 200 m transect as visual surveys.

We used microcassette recorders (Panasonic RN-202, Matsushita Electric Industrial Co., Ltd.) for fixed-position call surveys at each stream, twice each month, between 08:00 and 12:00. A recorder was placed on each side of the stream inside a plastic jug located 1.5 m up a tree. The two recorders were separated by an additional 200 m measured linearly along the stream bank. Each recording session lasted 60 min, resulting in 4 h of recording per site each month.

Trapping

In June a team of two workers installed four pitfall arrays and six funnel-trap arrays at the two sites. Arrays were equally divided between the two stream banks, 2 - 10 m from the water, and were separated by 50 m. Pitfall arrays consisted of four traps linked by drift fence, 30 cm high × 8 m long polyethylene strips attached to wooden stakes and anchored in the soil. Two traps were centrally located, on either side of the drift fence, and one trap was located at the end of either arm. Traps were buried plastic buckets, 24 cm deep and 24 cm wide, fitted with 7 mm^2 wire mesh funnels with 8 cm openings. Damp sponges were placed in each trap and twigs were inserted vertically to allow small mammals to escape. Arrays were left intact between monthly sessions, but traps were closed with plastic lids.

Funnel-trap arrays consisted of two collapsible fiber-mesh minnow traps (50 cm long × 25 cm high × 25 cm wide with two inward directed openings 5.5 cm in diameter; Nylon Net, Memphis, Tennesse) centrally located on either side of a drift fence (as described above). Litter was used to partially cover traps and to create "ramps" to funnel openings. Damp sponges were placed inside. Funnel traps were removed between monthly sessions, but drift fences were left intact.

During the three monthly sampling sessions, pitfall and funnel traps were open for 3 - 6 consecutive days and checked daily before noon. Information on captured amphibians was recorded as described for searches. For pitfall and funnel traps, we calculated the number of animals caught per trap-night (1 trap-night = 1 trap opened for 24 h).

Results

Visual surveys were the most effective sampling technique, in terms of the combined number of captures and observations (115), followed by pitfall arrays (10), funnel arrays (3) and live call surveys (2). Automated call surveys failed to record any amphibians. The two males heard calling were Western Toads at Crow Creek in June. Two Western Toads, one adult (37 mm SUL, pitfall trap) and one young-of-the-year (19 mm SUL, visual survey), were also captured at Crow Creek. All other amphibians encountered were Wood Frogs. The size distribution of Wood Frogs for all sampling combined was similar at the two sites: Bear Creek: mean SUL (mm) = 31.0 ± 9.4 (SD), range: 20 - 52.5, N = 35; Crow Creek: mean SUL = 39.8 ± 8.6, range: 20 - 59.5; N = 42. Most frogs captured were adults but we did record young-of-the-year (N = 19; 20 - 27 mm SUL) at both sites in July and August.

Survey results differed between sites and among months. Encounter rates during visual surveys and capture rates with funnel traps were greater at Crow Creek (Figure 1a, b). Pitfall capture rates were greater at Bear Creek (Figure 1b). Visual survey encounter rates and funnel-trap capture rates gradually decreased as the summer progressed (Figure 1c, d), whereas pitfall capture rates increased in August, reflecting captures of young-of-the year (Figure 1d).

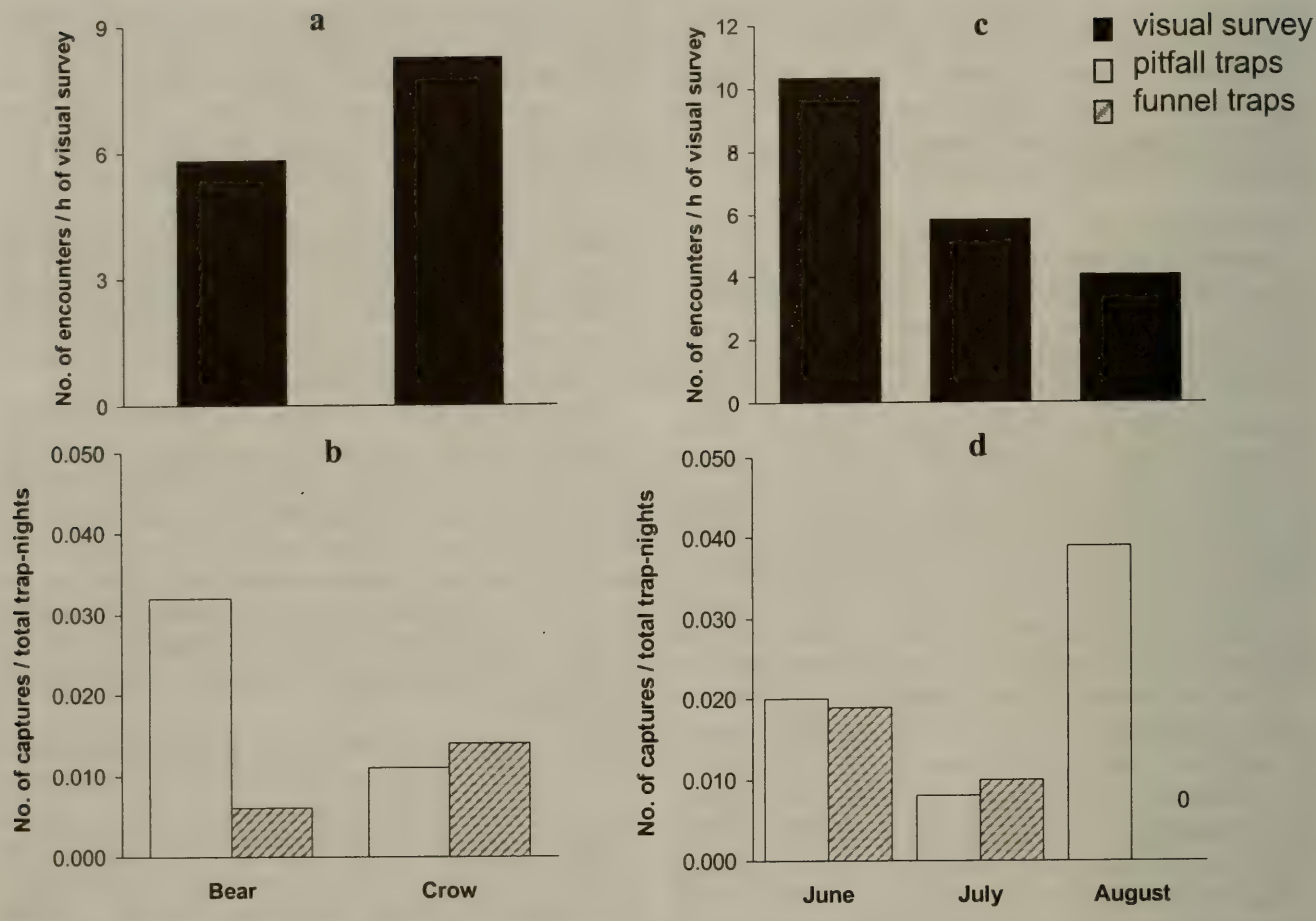

FIGURE 1. Encounter and capture rates for the Wood Frog at Bear Creek and Crow Creek using visual surveys (a), and pitfall and funnel traps (b) for the three monthly sampling sessions combined. Monthly encounter and capture rates for the Wood Frog using visual surveys (c), and pitfall and funnel traps (d) for the two sites combined. Total time devoted to visual surveys was 8.05 h at Bear Creek and 8.12 h at Crow Creek. Trapping effort totaled 216 pitfall and 156 funnel trap-nights at Bear Creek, and 188 pitfall and 140 funnel trap-nights at Crow Creek.

Discussion

We documented substantial differences in the performance of the four sampling techniques. Live and automated call surveys largely failed. The proposed AFBMP schedule for sampling streams simply does not coincide with the breeding season of anuran amphibians in boreal Alberta. Calling begins in late April, peaks in May and only *Bufo* species (which we did detect) continue breeding into June (Russell and Bauer 2000). Although relatively quick and easy, call surveys make little biological sense in this program.

Pitfall and funnel trapping sessions resulted in few amphibian records, accounting for only 10% of the total number of individuals. This was a disappointing performance considering that the two workers required 18 h and 13.5 h to install the full suite of pitfall and funnel-trap arrays, respectively. Using our pitfall trapping effort and design (16 traps in 4 arrays), two overnight trapping sessions were required to yield a 70% probability of capturing one Wood Frog. Funnel traps never even reached this level of performance. Trapping offers a reliable technique at sites where low travel costs and easy access permit sampling over an extended time period, particularly in upland habitats where amphibian densities are relatively low or occurrence sporadic (Szaro et al. 1988). Pitfall trapping did result in the capture of newly metamorphosed Wood Frogs, thus providing evidence of local breeding, possibly in Beaver (*Castor canadensis*) impoundments which were common on both streams.

Visual searches required relatively small investments in time and materials and proved to be the most successful technique for sampling streams. Wood Frogs were seen on 22 of 24 surveys. During these 22 surveys, searching along a transect for only 50 m offered a 70% probability of encountering at least one Wood Frog. Like pitfall trapping, visual searches encountered young-of-the year frogs. Visual surveys were well suited to the study streams because riparian areas were characterized by a low occurrence of woody debris and relatively sparse understory, features not shared by all forest streams in Alberta. Even our searches yielded fewer amphibians as the summer progressed and streamside grass-

es and forbs increased in height and density. Thus, although constrained visual searches might best meet AFBMP criteria, data generated by a single visit to a location will be strongly influenced by habitat structure, season, weather, time of day, and surveyor competence (Crump and Scott 1994).

Our surveys encountered only two of four anuran amphibians that occur in northeastern Alberta (Russell and Bauer 2000). As Roberts and Lewin (1979) reported from visual surveys conducted 20 years earlier, the Wood Frog overwhelmingly dominated our records. The absence of the common, but cryptic, Boreal Chorus Frog can be attributed to sampling biases linked to season (nonbreeding versus breeding and calling) and habitat (streams versus ponds). The paucity of toads may reflect insufficient sampling effort to detect these less abundant and more fossorial species.

If AFMBP maintains its proposed sampling protocols and adopts constrained visual searches to monitor forest amphibians, our study suggests that the program will reliably document the presence/absence of the Wood Frog at sites and collect some demographic information on poorly known western and northern populations (e.g., Leclair et al. 2000). It seems less likely that the program will be able to assess the health of boreal forest populations of amphibian species like the Canadian Toad which are of conservation concern in Alberta (Hamilton et al. 1998). In closing, we support amphibian surveys as part of innovative, large-scale projects such as the AFBMP. However, programs designed to sample simultaneously a large number of taxa over a large number of sites will inevitably result in compromises in terms of the types of data that can be collected for any given group of organisms and the accuracy of information concerning the distribution and status of species of interest.

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Notes

A Rare Leucistic Spiny Dogfish, *Squalus acanthias*, from the Bay of Fundy, Nova Scotia

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Coad, Brian W., and John Gilhen. 2002. A rare leucistic Spiny Dogfish, *Squalus acanthias*, from the Bay of Fundy, Nova Scotia. Canadian Field-Naturalist 116(1): 120–121.

A rare leucistic specimen of the Spiny Dogfish, *Squalus acanthias*, is reported for the first time in Nova Scotia, Canada and North America. It is a 915 mm total length adult female bearing pups. This specimen is an overall yellowish colour but has a large, darkly pigmented area on the head dorsally, a spot at the first and second dorsal fin origins, and blotches on the caudal peduncle and in the pectoral axils. It was captured while dragging for flounder in 70 fathoms about 2 km off Boars Head, Bay of Fundy, Nova Scotia, Canada at 44° 23′N, 66° 15′W, on 22 May 1989 by Stewart Taylor, Captain of the longliner *Nadia C* of Centreville, Digby County.

Key Words: Spiny Dogfish, *Squalus acanthias*, leucism, first record, Bay of Fundy, Nova Scotia, Canada.

On 22 May 1989, Stewart Taylor, Captain of the longliner *Nadia C* of Centreville, Digby County, was dragging for flounder in 70 fathoms, at a place known to fishermen as "Bear Cove Ground" about 2 km off Boars Head, Bay of Fundy, Nova Scotia, Canada at 44° 23′N, 66° 15′W, when he also captured a leucistic Spiny Dogfish, *Squalis acanthias*. It is a 915 mm total length adult female bearing pups, and is catalogued in the Nova Scotia Museum of Natural History as NSM85308.

Spiny Dogfish are normally grey to black in overall colour with conspicuous white spots on the flanks and a white belly. The Bay of Fundy specimen is an overall yellowish colour but has a large, darkly pigmented area on the head dorsally, a spot at the first and second dorsal fin origins, and blotches on the caudal peduncle and in the pectoral axils (Figure 1).

Albinism or leucism is rare in sharks, rays and their relatives although relatively common in bony fishes (Dawson 1964; 1966; 1971; Dawson and Heal 1976). Ben Brahim (1998) lists only 21 cases for 18 species in all the elasmobranchs. Additional records are given in Gopalan (1971) and Talent (1973) for a count of 24 cases for 20 species, 8 being total albinos, 12 being "partial" albinos (presumably leucistic), and 4 not clearly defined. Leucistic specimens have a paleness of colouration (Lincoln et al. 1982) with the eyes usually dark. The first record of a leucistic Spiny Dogfish in Canadian waters is therefore of some rarity.

Selected measurements on the specimen preserved in ethanol are as follows, with the methodology after Compagno (1984). Figures in parentheses are ranges for comparative material (NMC 66-600, 556 mm total length (TL), Nova Scotia, George's Bank, ca. 42°00′N, 67°00′W; NMC 84-1512, 623 mm TL, off Sable Island, ca. 44°18′N, 59°45′W; NMC 68-19, 665–704 mm TL, Newfoundland, St. John's, White's Ledge, ca. 47°42′N, 52°42′W; NMC 67–9, 80 mm TL, New Brunswick, Saint John River, 45°22′N, 66°12′W).

Prenarial length in preoral length 2.0 (1.8–2.0); narrowest mouth width in preoral length 1.5 (1.3–1.7); preorbital length in prebranchial length 2.6 (2.4–2.6); eye length in preorbital length 2.1 (1.9–2.3); first dorsal fin spine length in first dorsal fin height 1.4 (1.1–1.5); first dorsal fin height in fin length 2.1 (1.9–2.1); the second dorsal fin margin in first dorsal fin margin 1.3 (1.2–1.3). These morphometric characters fall within the ranges for normally coloured Spiny Dogfish and the leucistic specimen agrees with the description in Compagno (1984) in regards to other characters.

The specimen is leucistic with the overall skin colouration being a light yellowish. All fins in the preserved specimen have a light brownish appearance, apparently internal and possibly an artefact of preservation. The dorsal fin spines are blackish at their bases. The eyes are black. There is a rectangular patch on the dorsal head surface originating just posterior to the level of the spiracles and extending back over the pectoral fin. It becomes reticulated at the rear, and measures 71.6 mm in length and 24.5 mm in maximum width. An oval spot 5.9 mm long is at the first dorsal fin origin and a similar spot 5.6 mm long at the second dorsal fin origin. There is

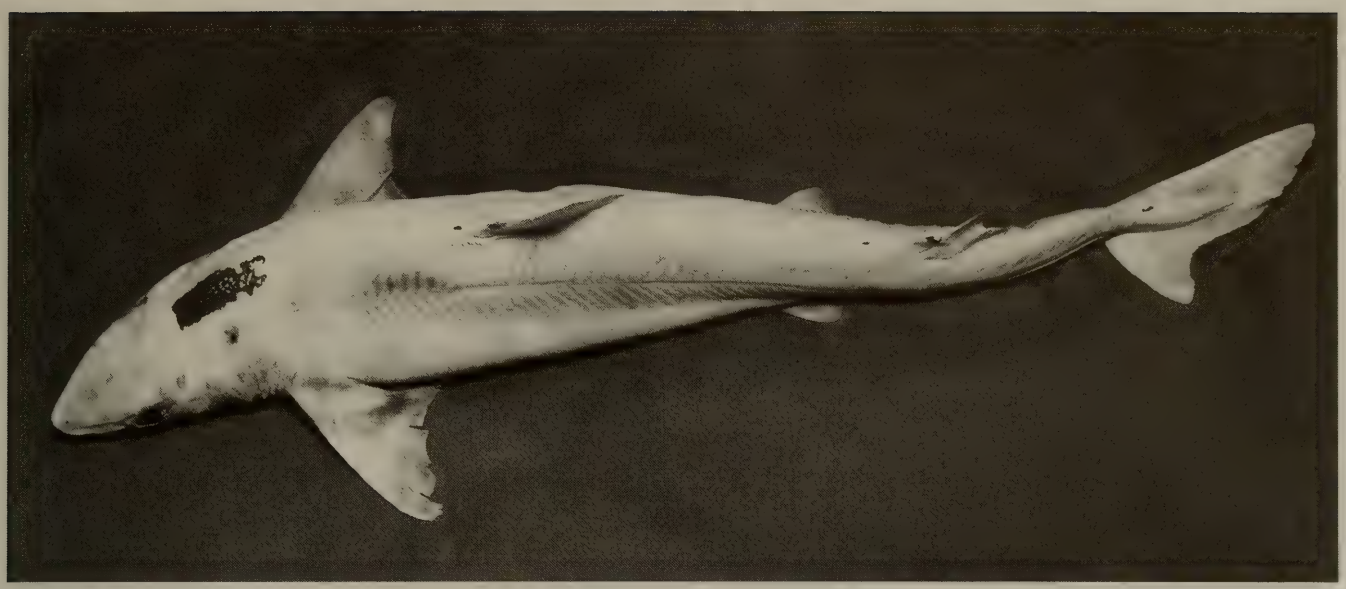

FIGURE 1. Dorso-lateral view of a rare leucistic Spiny Dogfish, *Squalus acanthias*, captured about 2 km off Boars Head, Bay of Fundy, Nova Scotia, Canada at 44°23′N, 66°15′W, by Stewart Taylor, Captain of the longliner *Nadia C*, of Centreville, Digby County, on 22 May 1989.

an elongate blotch 9.7 mm long on the left caudal peduncle upper margin somewhat behind the caudal fin origin, matched by a similar blotch 10.0 mm long on the right side but somewhat posterior to the one on the left; and a blotch, about 15 mm wide, concealed in each pectoral fin axil.

Frøiland (1975) provides the only other confirmed record of a leucistic Spiny Dogfish, taken in the North Sea in the late 1960s (with a verbal record of an earlier capture). This specimen was a female, 990 mm total length. Captain Taylor and other fishermen in the area of capture of the Nova Scotian specimen confirm that this is the first "pure white" dogfish seen. Normal-coloured dogfish were numerous in the area at the time of capture of the leucistic specimen.

Acknowledgments

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Anomalies in Incisor Wear of American Elk, *Cervus elaphus*, in the French River Delta, Ontario

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This article reports on limited observations of dental characteristics of American Elk introduced to the Burwash/French River area of Ontario from Alberta in the 1930s. Incisor wear was examined in 29 elk during a four-year study of two, geographically distinct herds. All examined adult elk from the French River delta (six females and four males) had excessive front incisor (I-1, I-2) wear as compared to adult animals from the Burwash region (five females, one male). No wear was ascertained in calves and yearlings belonging to the French River herd. Radio-monitoring of winter foraging behaviour of elk in the French River delta revealed frequent use of rock tripe (*Umbilicaria* spp.), scraped from cliff faces along waterway shorelines.

Key Words: American Elk, *Cervus elaphus*, incisor wear anomaly, Ontario.

Historically, the eastern American Elk (Wapiti) inhabited most of southern Ontario and south-western Quebec. However, due to over-hunting and habitat degradation, elk were extirpated from the eastern half of the continent by the late 1800s (Bosveld 1996*). The small elk population residing between the north shore of Georgian Bay, Lake Huron and Sudbury, Ontario (46.00°N, 80.50°W) are remnant animals from a 1930s introduction of Rocky Mountain elk from Alberta (Polziehn et al. 1998). For at least 30 years, these Ontario elk have existed in two relatively distinct herds, one in the French River delta on Georgian Bay (50 km south of Sudbury), and the other in the vicinity of the former Burwash Industrial Farm, 20 km south of Sudbury (Ranta 1979; Brown 1998). This area is located within the Great Lakes-St. Lawrence ecotone and associated with mixed conifer and hardwood forests (Rowe 1972). The climate in this region is continental with some moderating influences along Georgian Bay.

As a part of a wider investigation of the remnant elk herds, 16 animals were captured and radio-collared between 1994 and 1997 to determine habitat use and causes of mortality. Field necropsies were performed on all deceased animals (collared and non-collared) that could be located during the study. In total, the incisors of 29 captured and dead animals were examined (Table 1).

It was readily apparent that the incisor wear pattern differed between the two herds (Figures 1 and 2). The French River animals had severely worn lower incisors, especially I-1 and I-2. Animals between 6 and 15 years of age showed the highest amount of wear; however, no abrasion of lower incisors was apparent in calves nor yearlings. Elk replace their deciduous I-1 at 15 months of age and I-2 at 18 months (Bubenik 1982). Monitoring of winter foraging behaviour of instrumented animals revealed frequent scraping of lichens, particularly rock tripe, from steep cliff faces along the French River delta waterways. The use of lichens coincided with increased browsing on conifers during late winter (February-March). Among the consumed conifers were Common Juniper (*Juniperus communis*), Eastern White Cedar (*Thuja occidentalis*), and White Pine (*Pinus strobus*) (Jost et al. 1999). Animals from the Burwash herd also consumed conifers, but showed normal incisor wear. The variation in incisor wear appeared to result from differences in regional topography. The Burwash region had more rolling terrain, fewer cliff faces, and fewer waterways as compared to the French River delta.

It is generally known that lichens comprise a large portion of the winter diet of Caribou and Reindeer (*Rangifer tarandus*) and are high in digestible carbohydrates and low in nitrogen (Thomas et al. 1984). Elk wintering in mature conifer forests in the Rocky Mountains readily consumed arboreal lichens (Hash 1973; Bohne 1974). Usnic acid is a common secondary compound found in lichens (Culberson 1977) and data collected by Palo (1993) suggested that the addition of usnic acid to hay resulted in higher *in*

TABLE 1. Number of examined animals in 3 age classes and 2 herds.

Herd	calves (0.5–1 year)	yearlings (1.5–2 years)	adults (2.5–15 years)
Burwash	6	2	6
French River	1	4	10

Figure 1. Lower incisors of adult elk from the French River population, near Sudbury, Ontario showing severe wear associated with scraping lichens from cliff faces.

FIGURE 2. Lower incisors of adult elk from the Burwash population, showing a normal wear pattern.

vitro dry matter digestibility. Jenks and Leslie (1988) also found that *in vitro* digestion of White-tailed Deer (*Odocoileus virginianus*) forage was enhanced by lichens, increasing fermentation efficiency and forage digestibility. In the present study, use of lichens coincided with high snow depths and increased utilization of conifers during late winter (February and early March) and to a lesser extent early spring (late March and April). It is suggested that where available, rock tripe consumption enhanced the digestibility of conifers and other woody browse consumed by the studied elk in late winter and contributed to the observed variation in tooth wear patterns.

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First record of the Hoary Bat, *Lasiurus cinereus* (Chiroptera: Vespertilionidae), from Prince Edward Island.

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McAlpine, Donald F., Frances Muldoon, and Alexander I. Wandeler. 2002. First record of the Hoary Bat, *Lasiurus cinereus* (Chiroptera: Vespertilionidae), from Prince Edward Island. Canadian Field-Naturalist 116(1): 124–125.

The Hoary Bat, *Lasiurus cinereus*, is reported from Prince Edward Island for the first time on the basis of an adult animal collected 17 August 1999 and submitted for rabies testing. Based on previous records for this species from the Atlantic region, the presence of the Hoary Bat on Prince Edward Island is not unexpected. Although *Lasiurus cinereus* appears to be rare in the province, bat surveys that might better establish the species status on the Island are lacking.

Key Words: Hoary Bat, *Lasiurus cinereus*, new record, Prince Edward Island.

The Hoary Bat, *Lasiurus cinereus,* is the most widespread of North American bats, and although infrequently encountered, is widely distributed in Canada (van Zyll de Jong 1985). Maunder (1988) summarized the 17 records for Atlantic Canada up to that time, including the first occurrence from Newfoundland. Previously, *Lasiurus cinereus* has not been recorded on Prince Edward Island, and has been considered hypothetical for Kouchibouguac National Park, which borders the coast of New Brunswick adjacent to the Island (Maunder 1988; Tremblay 1992). However, recent acoustic surveys revealed the species presence in the park (H. Broders, personal communication to DFM). Based on these earlier reports from the region, the presence of *Lasiurus cinereus* on Prince Edward Island was not unexpected.

The first specimen of the Hoary Bat on Prince Edward Island was collected 17 August 1999, at Charlottetown, Queens County, and submitted to the Canadian Food Inspection Agency for rabies testing. Although the rabies specimen submission form records that the animal was aggressive and was killed, it was negative for rabies virus. Only the head was submitted and it has now been deposited in the New Brunswick Museum collection (NBM 5801). The head includes the skull, with cranium slit, of an adult animal with pelage intact across the muzzle and the lower jaws posterior to the eyes.

Nearly all records for the Hoary Bat in Atlantic Canada have been individuals encountered in late summer and autumn, with the Prince Edward Island record reported here following this pattern. Maunder (1988) suggested that late autumn tree bats may be present in the Atlantic region as a result of "drift migration" and van Zyll de Jong (1985) noted that this species has been recorded from widely scattered locations far beyond areas that appear to offer suitable habitat. Although *Lasiurus cinereus* appears to be rare on Prince Edward Island, bat surveys that might better establish the species status on the Island are lacking.

To date there is no evidence that the Hoary Bat breeds in the Atlantic region. Although there are two mid-July occurrences for Quebec (Pierre Aquin, personal communication to DFM) there are only two July records for Maritime Canada, both for New Brunswick (12 and 29 July, NBM 1163, Tremblay 1989*). All other reports of the Hoary Bat from the Atlantic Provinces are from early August to 17 November.

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Wolf, *Canis lupus*, Response to Domestic Sled Dog, *Canis familiaris*, Activities in Central Yukon

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Kuzyk, Gerald W., and Kristin M. Kuzyk. 2002. Wolf, *Canis lupus,* response to domestic sled dog, *Canis familiaris,* activities in central Yukon. Canadian Field-Naturalist 116(1): 125–126.

We present an observation of a lone Wolf (*Canis lupus*) regularly following teams of domestic sled dogs (*Canis familiaris*) and humans for distances up to 34 kilometers. The lone Wolf died of unknown causes, approximately 30 meters from a trapping trail used by sled dog teams and within vocalization distance of sled dogs at an occupied cabin. We also noted a pack of about seven Wolves that did not follow the same sled dog trail when they encountered it, and exchanged vocalizations with the dogs. We suggest human-made trails can be especially important travel corridors for lone Wolves.

Key Words: Wolf, *Canis lupus*, Dog, *Canis familiaris*, Black Bear, *Ursus americanus*, Lake Whitefish, *Coregonus clupeaformis*, travel corridor, Yukon, howling, communication.

Wolves (*Canis lupus*) are ancestors of domestic dogs (*Canis familiaris*) (Morey 1992); are known to interbreed with dogs (Maagaard and Graugaard 1994); to aggressively interact with, and prey upon dogs (Tompa 1983); and to closely follow travelling sled dog teams (Karras 1975). Coppinger and Coppinger (1995) reviewed literature of livestock guard dogs in Europe and Asia, and applied this information to a study of Wolves and guard dogs in Minnesota, concluding that Wolves can treat dogs as conspecifics and not as prey. Reports of Wolf-dog interactions in the scientific literature are scarce (Fritts and Paul 1989), especially in areas of low human activity. In Yukon, most known Wolf-dog encounters are predatory, and usually occur in autumn and winter (Alan Baer, Yukon Fish and Wildlife Branch, personal communication).

From September 1991 to February 1992 we used 13 sled dogs for the purpose of trapping, south of Mayo in central Yukon (63° 30' N 135° 30' W). On 9 October 1991, at approximately 09:00 and 12:00 h, a pack of Wolves was heard howling within a couple kilometers of our trapline cabin. There was no response from the sled dogs that were chained separately within 40 meters of the trapline cabin. On 10 October a small Wolf track, presumably that of a pup, was noticed in the fresh snow within ten meters of a sled dog chained at the outside edge of the group of dogs. Two of the dogs had barked that night, but the cause may have been a Black Bear (*Ursus americanus*), as its tracks in fresh snow were noticed within 75 meters of the cabin. On 12 October, about two kilometers from the cabin, we discovered a Lake Whitefish (*Coregonus clupeaformis*) spawning run in a small narrows of less than five meters wide that was being used by a pack of Wolves and a Black Bear. Wolf and Black Bear tracks were obvious in the fresh snow near the creek. Whole and partially eaten Whitefish, as well as a cache of buried Whitefish, were found on the creek bank. The Wolves remained near the fish run for seven days until 19 October when the ice thickened and the fish run neared completion.

On 8 December at 10:45 h, excited barking from the sled dogs drew our attention to a lone gray Wolf on the lake ice approximately 400 meters from our cabin. It quickly fled into the forest when it noticed humans near the cabin. The same afternoon, a single fresh Wolf track was seen on the main trapping trail, which had initially been made with snowshoes, and was regularly used for travel with sled dogs. A lone Wolf traveled on the trapping trail for approximately five kilometers and showed interest in a trap set for Wolverine (*Gulo gulo*) that had a Moose (*Alces alces*) head for bait. On the morning of 11 December a single large fresh Wolf track was noticed within 30 meters of a sled dog chained at the periphery of the group of dogs. A Wolf remained in the area of the cabin, successfully taking bait from traps and scavenging cached Whitefish at the creek narrows for the next couple days. On 14 December a Wolf was caught in and then escaped from a #4 long spring

trap, set for Lynx (*Lynx canadensis*). The same evening from approximately 19:00–19:15 h, howling from a single Wolf was heard across the lake from the cabin, with no reply from the dogs.

In late December and early January, lone Wolf tracks were a frequent occurrence on and near the main trapping trail. On the morning of 17 January 1992, we left the main cabin and traveled 17 kilometers to a smaller line cabin. During the night there was a light snowfall and the following morning, we noticed a single fresh Wolf track 30 meters from the cabin. A female sled dog in estrous was tied near the front door of the cabin, and no barking by the dogs was heard at night when the Wolf was nearby. On 19 January, during the return trip to the main cabin, we encountered a single fresh Wolf track in the snow, which suggested the same lone Wolf had followed us to the small line cabin. On 20 January, a fresh lone Wolf track was observed within two kilometers of the main cabin, suggesting the same individual Wolf had followed us on the return trip back to the main cabin, a distance totaling approximately 34 kilometers. Wolves maintain their territories by killing trespassing Wolves (Mech 1991), so during this foray, the lone Wolf had traveled well inside an occupied Wolf pack territory and risked being killed by territorial Wolves.

On 23 January at about 10:00 h, and approximately three kilometers from the main cabin, excitement from the team of sled dogs alerted us to a dead Wolf in its bed about 30 meters from the trapping trail. We assume it was the same Wolf that had been in the locality, due to the gray pelage and the fact that following this discovery, we saw no more evidence of lone Wolf tracks on the trails and heard no more howling from a single Wolf. The cause of the Wolf's death was undetermined; there were no signs of external injuries from other Wolves and rigor mortis had not occurred. The Wolf was an old male as determined by tooth wear, and was in an emaciated state, as indicated by the lack of body fat and protruding ribs, although the coat was still in prime condition. We believe the site of death for this Wolf was not random because it was only a short distance from the compacted trail the Wolf had used in recent travels. The site was also within vocalization distance of sled dogs and in view (three kilometers across a valley) of the occupied cabin. Human-made trails can provide easier movement for Wolves (James 1999) and as in this case, may be especially important for lone Wolves in poor condition.

On 25 January 1992 a pack of an estimated seven Wolves encountered our trapping trail on a narrow creek, the same one used by the lone Wolf. There was little snow at this location and the Wolves fanned out and did not follow the trail off the creek. On 2 February at approximately 12:00 h, while we were resting the two dog teams near the same location, a pack of Wolves began howling approximately five kilometers away. The air was still, the sky sunny and the temperature estimated at -20C. All the dogs became attentive, looked in the direction of the Wolves and began synchronously howling for approximately one minute. They then became silent and attentive, looking in the Wolves' direction. The Wolves and sled dogs exchanged howls once more, then there was prolonged silence and we left the area. Wolves howl as a means of territorial maintenance and as communication within and between packs (Harrington and Mech 1979). No scientific reference was found of Wolves and dogs communicating through howling, so this observation may help in further understanding Wolf-dog interactions.

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First Record of an Eastern Coyote, *Canis latrans*, in Labrador

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An adult male Eastern Coyote, *Canis latrans*, trapped on 14 January 1995 along the Churchill River, is the first confirmed record for Labrador. This record is approximately 600 km north east of the previously accepted range limit in eastern Canada.

Key Words: Eastern Coyote, *Canis latrans*, range, distribution, Labrador.

Coyotes (*Canis latrans*) have been expanding their range northward and eastward in North America during the past century (Perkins and Mautz 1990; Thurber and Peterson 1991; Lehman et al. 1991; Parker 1995). Coyotes were first recorded in Québec in 1944 (Rand 1945) and had spread north across the Gaspé Peninsula by 1974 (Georges 1976). More recently, Coyotes have become established as a significant component of the boreal forests of southeastern Québec (Crête and Desrosiers 1995; Tremblay et al. 1998; Patterson et al. 1999). Coyotes immigrated to the island of Newfoundland on drifting pack ice and were first documented in 1985 (Parker 1995). Here, we report the first record of an Eastern Coyote in Labrador, approximately 600 km north east of the previously recorded range limit in Québec (George 1976; Parker 1995).

On 14 January 1995, an adult male Coyote was trapped along the Churchill River (53°17' N, 60°15' W), approximately 2 km south east of Happy Valley–Goose Bay. The Coyote was estimated (F. Blake, personal communication) to weigh approximately 15 kg. Although the weight could not be confirmed, it is consistent with reported average weights of 13.5 kg, and 12.5 kg for adult male forest Coyotes in Québec (Tremblay et al. 1998; Poulle, M.-L. et al. 1995) and about half the weight (ca. 30 kg) of Wolves (*Canis lupus*) in Labrador (Parker and Luttich 1986). Dr. C. G. van Zyll de Jong of the National Museum of Natural Sciences, later examined the skull and performed a quantitative comparison of the Goose Bay skull with samples of Coyotes and Wolves of both sexes using a ratio diagram (Figure 1). Eleven different dimensions of the skull (see Nowak 1979) for each of the taxa and the Goose Bay specimen were compared. All measurements were converted into logarithms and the sample of male Wolves was used as the standard. The difference (d) between the logarithmic value of the standard and the other groups and the Goose Bay specimen were calculated, plotted and connected by lines to aid in their interpretation (Figure 1). This comparison revealed that the Goose Bay skull ratio series was similar to those of the male and female Coyote samples and within two standard deviations from the male Coyote sample means. These results confirmed its identification as that of a large adult male Coyote (Dr. C. G. van Zyll de Jong, 17 December 1995, personal communication). Recent information on expanding Coyote populations in eastern Québec also indicates that Coyotes appear to be larger in the eastern portion of their range (Thurber and Peterson 1991; Larivière and Crête 1993).

Although no previous records of Coyotes exist for Labrador, the possibility of an established population remains plausible, as they do coexist with Wolves in Alaska (Thurber and Peterson 1991), Alberta, British Columbia, and more recently Idaho (Pilgrim et al. 1998). No geographic barriers seem to exist to prevent Coyotes from extending their range northward into Labrador. Delineation of Coyote range expansion in Labrador may have been precluded by the fact that no systematic surveys have been conducted for any carnivore species in Labrador and low fur prices in the last decade have significantly decreased trapping effort resulting in only one specimen to date. The expansion of Coyotes into eastern forests has occurred due to high populations of White-tailed Deer (*Odocoileus virginianus*), high populations of humans and associated garbage, and changes in forest communities, all of which have resulted in an improvement in food supply (Thurber and Peterson 1991; Tremblay et al. 1998). Both sedentary and migratory Caribou (*Rangifer tarandus*) herds frequent central and southern Labrador and Coyotes have been identified as a threat to remnant populations of Woodland Caribou in southeastern Québec (Crête and Desrosiers 1995). Recent extensions of the winter range by migratory Caribou from the George River Caribou herd (Department of National Defence, unpublished data), and increased numbers of Moose (*Alces alces*) in southern Labrador

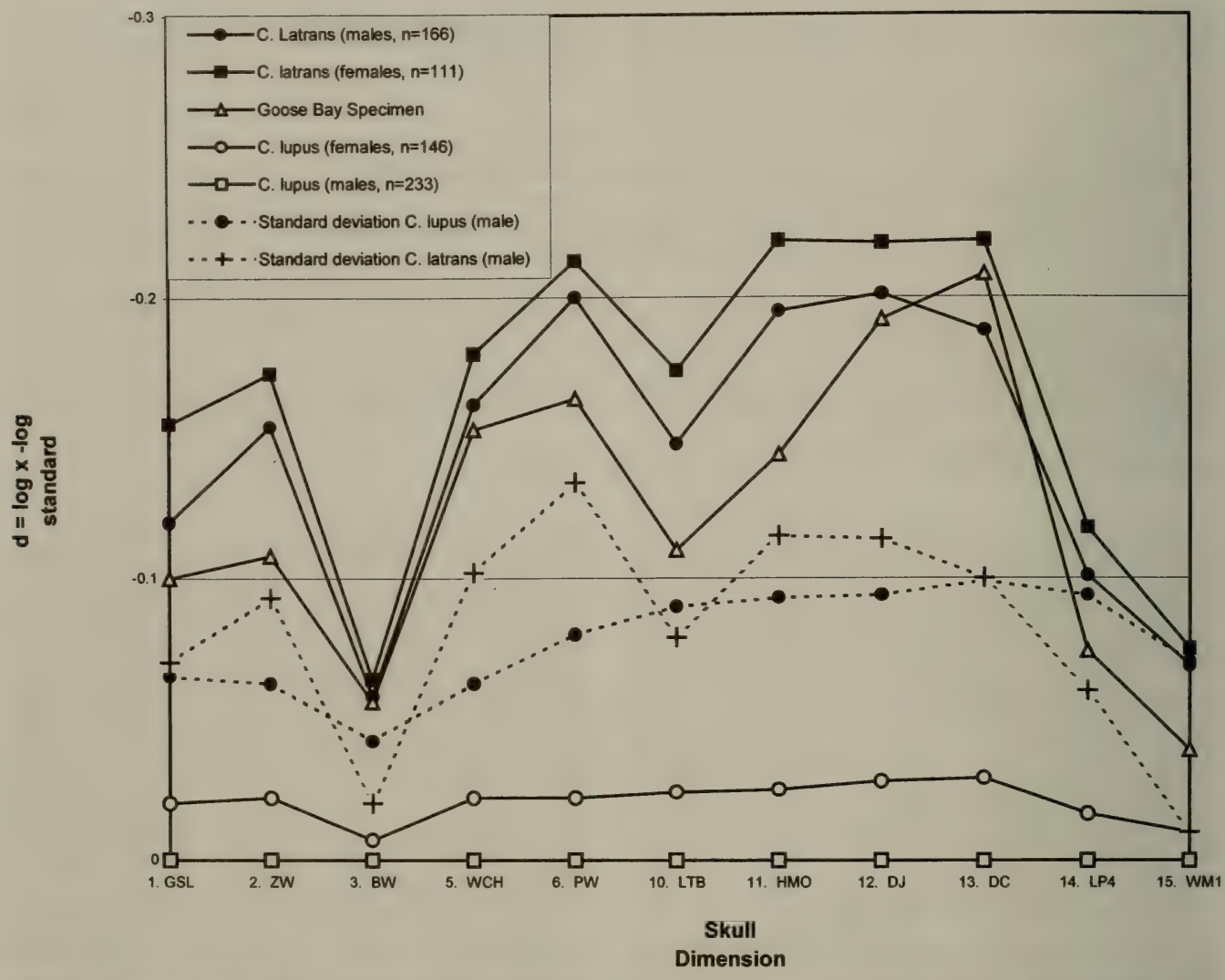

FIGURE 1. Ratio diagram comparing eleven standard cranial measurements of the Goose Bay, Labrador specimen with samples of male and female *Canis lupus* and *C. latrans*. For a description of measurements and samples of *C. lupus* and *C. latrans* see: Appendix B in Nowak (1979).

(Chubbs and Schaefer 1997) may provide a sufficient prey and carrion base to support Coyotes through the winter. Coyotes are a highly adaptable species (Pilgrim et al. 1998) and are capable of remaining in an area with a seasonally reduced prey base and harsh weather conditions (Patterson et al. 1999). Although the boreal forest appears to be a relatively poor habitat for Coyotes (Tremblay et al. 1998), Coyotes can persist at low densities, depending mainly on Snowshoe Hares (*Lepus americanus*), mice and voles (Patterson et al. 2000; M. Crête personal communication). It has been known for some time (Lehman et al. 1991; Pilgrim et al. 1998) that hybridisation of Wolf and Coyote genotypes has already occurred in Québec due to the rapid northeast progression of Coyotes.

Although this single record may not confirm a range extension, the potential for Coyote range expansion into Labrador appears to be plausible and even likely. The sparse human population of Labrador, lack of systematic surveys, and decreasing trapping effort may result in an existing sparse population going undetected. Despite the presence of a healthy Wolf population, which may limit or slow down colonisation through intraguild predation, the increasingly human-transformed landscape may be the key to the establishment of Coyotes in Labrador.

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Long Distance Movement by a Coyote, *Canis latrans*, and Red Fox, *Vulpes vulpes*, in Ontario: Implications for Disease-spread

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During a rabies control program in southern Ontario, Raccoons, (*Procyon lotor lotor*), Striped Skunks (*Mephitis mephitis*), Red Foxes (*Vulpes vulpes*), and Coyotes (*Canis latrans*) were live-captured, vaccinated, ear-tagged, and released at point of capture. One of eight Coyotes captured and released during 1995 in Niagara Falls, Ontario, dispersed 320 km to Coatsworth, Ontario. Additionally, 1 of 23 foxes, captured and released in Scarborough, Ontario, during 1994, moved 170 km to Rossmore, Ontario. Although such long distance movements are probably rare in Ontario they may play a critical role in the dissemination of infectious diseases such as rabies.

Key Words: Red Fox, *Vulpes vulpes*, Coyote, *Canis latrans*, rabies, movement, dispersal, Ontario.

As part of a Provincial strategy to prevent raccoon rabies from becoming established in Ontario, the Ontario Ministry of Natural Resources (OMNR) implemented a Trap-Vaccinate-Release (TVR) program in the Niagara Frontier (Rosatte et al. 1997). Since 1994, personnel from the OMNR Rabies Research Unit have been live-capturing and vaccinating Raccoons (*Procyon lotor*), Striped Skunks (*Mephitis mephitis*), Red Foxes (*Vulpes vulpes*) and Coyotes (*Canis latrans*) in a 680 km^2 area encompassing Niagara Falls, Ontario. During the 1995 Niagara TVR program, eight Coyotes were live-captured, vaccinated, ear-tagged, and released at the point of capture in the City of Niagara Falls. One of the Coyotes, a juvenile male, released on 26 July 1995, was shot by a hunter near the town of Coatsworth, Ontario, during February 1996; a straight line distance of 320 km west (Figure 1). All local

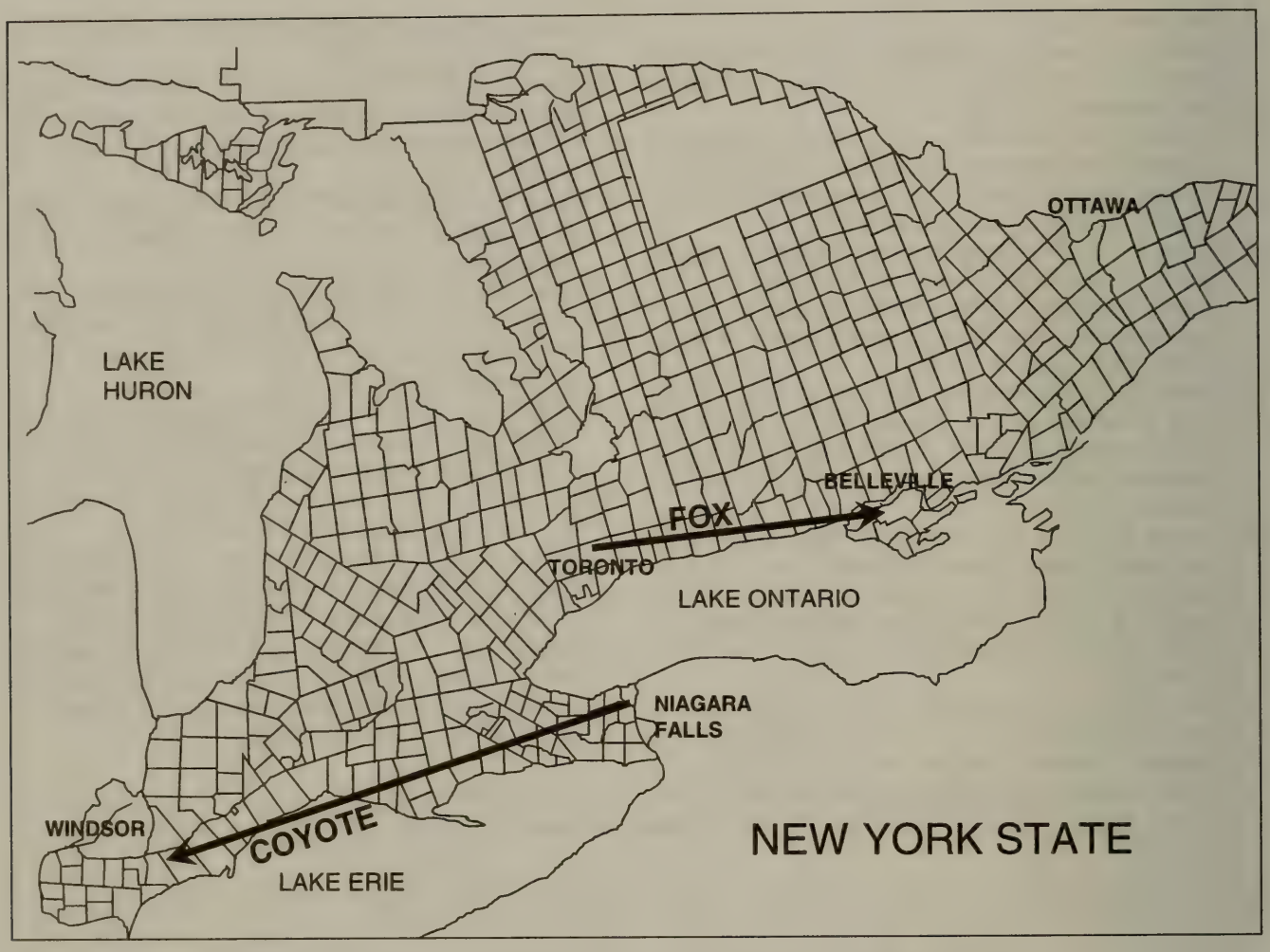

FIGURE 1. Dispersal direction of a Coyote and a Red Fox in Southern Ontario.

humane societies and animal control agencies in the Niagara TVR area were questioned and none had relocated any Coyotes between July 1995 and February 1996.

From 1987–1997, the OMNR Rabies Research Unit conducted a TVR program to control rabies in Skunks in the city of Scarborough, Ontario. About 3200 Striped Skunks, 11 300 Raccoons and 100 Red Foxes were live-captured, vaccinated, ear-tagged, and released (Rosatte et al. 1992). During the 1994 Scarborough TVR program, three Red Foxes were captured, vaccinated, ear-tagged, and released at point of capture. On 2 January 1996, a trapper captured one of the foxes near Rossmore, Ontario; a straight line distance of 170 km east (Figure 1). This fox, an adult female in 1996, was originally captured as a juvenile in Scarborough on 19 August 1994.

During 1996–1999, 127 Red Foxes and 13 Coyotes were ear-tagged during TVR operations conducted by OMNR in Niagara, Scarborough, and Brockville. No significant movements such as those noted above were reported.

Discussion

In Ontario, juvenile Red Foxes and Coyotes usually disperse during their first fall or winter (Voigt 1987; MacDonald and Voigt 1985; Voigt and Berg 1987). Researchers in one rural Ontario study determined that Coyote movements ranged from 16 km to 152 km (Kolenosky et al. 1978). Dispersal of juvenile male and female Red Foxes in another study in rural Ontario averaged 30 km and 8 km, respectively. Few individuals dispersed more than 100 km (one juvenile male Red Fox dispersed 122 km with > 120 total Foxes collared) (Voigt 1987; Voigt and MacDonald 1984). Similarly, in Toronto, long distance dispersal was rare; only 2 of 33 radio-collared Red Foxes dispersed over 100 km (Rosatte unpublished; Rosatte et al. 1991).

Although the movements noted in this study (320 km for the Coyote and 170 km for the Red Fox) are exceptional for Ontario, similar movements have been reported elsewhere. For example, Carbyn and Paquet (1986) recorded a 544 km movement of an adult female Coyote that dispersed from Manitoba to

Saskatchewan. Additionally, one sub-adult male Red Fox moved 395 km from Wisconsin to Indiana (Ables 1965). However, such long distance dispersals appear to be rare.

The last major wildlife rabies epizootic in Canada occurred in the Arctic during the 1940s (Tabel et al. 1974). Numerous wildlife species including Red Foxes and Coyotes were reported with rabies as the disease dispersed into the Canadian provinces from the Northwest Territories in the 1950s (Tabel et al. 1974). The epizootic reached southern Ontario in 1956 due mainly to the movements of infected Red Foxes (Johnston and Beauregard 1969). Fox rabies remained enzootic in southern Ontario since the 1950s, however, the prevalence of that disease has recently declined dramatically due to rabies management programs involving the use of oral rabies vaccine baits and TVR (MacInnes 1987; Rosatte et al. 1992; Rosatte et al. 1993). Dispersing Red Foxes and to a lesser extent Coyotes (as Red Foxes are the primary vector of the Arctic fox strain of rabies) in Ontario have likely played a major role in the maintenance of the disease as well as in the initiation of new outbreaks (MacInnes 1987; Johnston and Beauregard 1969; Tabel et al. 1974). To minimize the risk of dispersing Red Foxes contributing to the spread of rabies in Ontario, OMNR is annually distributing oral rabies vaccine baits over areas that include a 50 km buffer around any rabies case.

Based on observations from this study, long-distance movements by Red Foxes and Coyotes likely are rare. However, biologists should consider the potential maximum dispersal of Red Foxes and Coyotes when planning or implementing a rabies management strategy for Ontario or other areas where either of these two species occur.

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Predation by Wolves, *Canis lupus*, on Wolverines, *Gulo gulo*, and an American Marten, *Martes americana*, in Alaska.

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White, Kevin S., Howard N. Golden, Kris J. Hundertmark, and Gerald R. Lee. 2002. Predation by Wolves, *Canis lupus*, on Wolverines, *Gulo gulo*, and an American Marten, *Martes americana*, in Alaska. Canadian Field-Naturalist 116(1): 132–134.

We report three instances of Wolf predation on mustelids in Alaska; two involved Wolverines and another involved an American Marten. Such observations are rare and in previous studies usually have been documented indirectly. This account provides insight into the potential role of Wolves in influencing mesocarnivore communities in northern environments.

Key Words: Wolf, *Canis lupus*, Wolverine, *Gulo gulo*, Marten, *Martes americana*, predation, Alaska.

Observations of Wolf (*Canus lupus*) -carnivore interactions are rare and have generally focused on those concerning ursids (*Ursus arctos*, Grizzly Bear; and *U. americana*, Black Bear; Murie 1944; Mech 1970, Rogers and Mech 1981; Ballard 1982) and canids (*Canis latrans,* Coyotes, and *Vulpes vulpes*, Red Foxes; Stenlund 1955; Mech 1970; Berg and Chesness 1978; Peterson 1996; Crabtree and Sheldon 1999). Nevertheless, direct and indirect evidence suggests that interactions involving actual and attempted Wolf predation on mustelids (Stenlund 1955, Boles 1977, Route and Peterson 1991, Boyd et al. 1994, Paragi et al. 1996, Kohira and Rextad 1997; Mech et al. 1998) can occur at low frequency in some regions of North America and, further, may have a significant effect on mustelid populations (Palomares and Caro 1999). We report here on observations of Wolverine, *Gulo gulo*, and American Marten, *Martes americana*, predation by Wolves in Alaska.

Account 1: On 20 March 1983 (1330 PST), during an aerial sex and age composition survey for Moose (*Alces alces*), we observed an adult Wolverine in the top of a large cottonwood (*Populus trichocarpa*) tree along the Chilkat River near Haines in southeastern Alaska (59° 37'N, 135° 55'W). Near the base of the tree was a pack of at least five Wolves in an area of blood-stained snow where the Wolves appeared to have been digging. One Wolf was observed with a juvenile Wolverine in its mouth. A few of the other Wolves were digging in the snow at what we suspected was a Wolverine den site, while another Wolf was lying down a short distance from the activity. Our impression was that the Wolves found the Wolverine den by chance and were in the process of digging it out to get to the kits. We were unable to determine if the Wolves actually consumed any of the kits, but judging from the extent and dispersion of blood on the snow, more than one kit had been killed.

Account 2: We believe Wolves were responsible for the death of a yearling female Wolverine in an area of light spruce (Picea spp.) forest and tundra vegetation in the Nelchina Basin in southcentral Alaska (62° 41'N, 147° 45'W). On 1 June 1997, while radio-tracking Wolverines as part of a population ecology study (Golden 1997), we observed a Wolf circling a yearling female Wolverine whose radio collar was on mortality mode and which showed no sign of movement (S. D. Bowen, Alaska Department of Fish and Game, personal communication). This was the first day we had detected her radio signal on mortality mode since she was last seen alive on 15 May 1997. We retrieved the carcass by helicopter on 2 June 1997. While the carcass was being loaded onto the helicopter, two Wolves stood within 300 m barking and howling (J. W. Testa, Alaska Department of Fish and Game, personal communication). The necropsy revealed five puncture holes in the skin, three in the chest and two in the groin, which may have been made by canine teeth of Wolves. Its chest was crushed laterally on the ventral side, resulting in several broken ribs. Although the carcass was in an advanced state of decomposition, it was intact and no part of it had been consumed. These observations plus the behavior of the Wolves and the timing of the death in late May suggest Wolves attacked and killed the Wolverine, possibly in defense of a wolf den site.

Account 3: On 8 June 2000 (1222 ADT) during a telemetry re-location flight, we observed a radio-

collared, solitary female Wolf in mixed-spruce (*P. glauca* and *P. mariana*) forest vigorously digging in moss-covered, hummocky soil, near Old Man Lake, Alaska (62° 31'N, 146° 81'W). As we circled the Wolf, we noticed one American Marten escaping through the forest ~15 m away as the Wolf continued digging in the original location. Subsequently, after ~2 minutes of digging, we observed the Wolf drag another Marten with its jaws from the underground cavity that it had been excavating. The Wolf then repeatedly bit, shook and dropped the Marten 4–5 times until the Marten stopped moving, at which time it was presumed dead. The Wolf first stood guarding, and then rolled on the carcass until we terminated our observation at 1231 (ADT).

Our observations indicated, to the extent possible, that Wolves did not feed on the carcasses of the Wolverines they had killed, a behavior noted by others (Burkholder 1962, Boles 1977). We can only speculate on the basis of that behavior, but ultimate explanations might include: elimination of competitors, defense of offspring, availability of prey, or disturbance by human observers.

The role of Wolves in structuring mesocarnivore communities is suspected to be significant though not fully understood. In areas where Wolves are recolonizing historic ranges following prolonged absences, behavioral and ecological modifications of mesocarnivores can be dramatic (Crabtree and Sheldon 1999). Such changes underscore the importance of Wolves in influencing ecosystem dynamics in such areas. While Wolf populations have fluctuated historically in Alaska, their presence has remained constant and their role in influencing ungulate populations has been studied extensively (Gasaway et al. 1983; Ballard et al. 1992; Dale et al. 1994; Adams et al. 1995), though their interactions with mesocarnivores has received little attention. When considering species such as Wolverines that typically occur at low density, it is important to recognize the role that even limited predation might exert on their population dynamics. Thus, in such cases, anecdotal accounts of predator-specific mortality provide valuable insights into the range of influence that Wolves might exert on mesocarnivore communities in relatively undisturbed northern environments.

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Meek's Halfbeak, *Hyporhamphus meeki*, and Flying Gurnard, *Dactylopterus volitans*, captured in the Annapolis Basin, Nova Scotia

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Gibson, A. Jamie F., and Ransom A. Myers. 2002. Meek's Halfbeak, *Hyporhamphus meeki*, and Flying Gurnard *Dactylopterus volitans*, captured in the Annapolis Basin, Nova Scotia. Canadian Field-Naturalist 116(1): 134–135.

We report the capture of several unusual fish at a hydroelectric generating station, Annapolis Royal, in the Annapolis Basin, Nova Scotia, during the fall of 1999. These include a Meek's Halfbeak, *Hyporhamphus meeki*, that is either the first or second Canadian record for this species and a Flying Gurnard, *Dactylopterus volitans*, that is a first record for the Bay of Fundy. Additionally, three Bluefish, *Pomatomus saltatrix*, and a Fourbeard Rockling, *Enchelyopus cimbrius*, were reported for the first time from the Annapolis Estuary during 1999.

Key Words: Meek's Halfbeak, *Hyporhamphus meeki*, Flying Gurnard, *Dactylopterus volitans*, Bluefish, *Pomatomus saltatrix*, Fourbeard Rockling, *Enchelyopus cimbrius*, Annapolis River, Bay of Fundy, Nova Scotia, distribution.

The Annapolis Basin in Nova Scotia is home to the western hemisphere's only tidal hydroelectric generating station, located in Annapolis Royal (44° 45′N, 65° 31′W). As such, fish assemblages within the estuary are well studied, during both pre-operational stock assessments and surveys (e.g., Melvin et a. 1985; Jessop 1976), and several assessments of fish passage facilities at the generating station (e.g., Gibson 1996). During 1999, several unusual fish specimens were captured while testing the effectiveness of an ultrasound fish diversion system at the station (Gibson and Myers 2000). A Meek's Halfbeak, *Hyporhamphus meeki*, captured on 23 September, 1999, is either the first or second record of this species in Canada, and is the first record in 50 years. A Flying Gurnard, *Dactylopterus volitans*, captured 28 September 1999, is a first record for the Bay of Fundy. Other unusual specimens captured at this location during September 1999 include three Bluefish, *Pomatomus saltatrix* and one Fourbeard rockling, *Enchelyopus cimbrius*. While these latter species occur regularly in the Bay of Fundy (Scott and Scott 1988), these species have not been reported previously in the Annapolis Estuary.

Hyporhamphus spp. are planktivorous fish characterised by a very long lower jaw and short upper jaw. The taxonomic status of western Atlantic *Hyporhampus* was clarified by the description of a new species, *Hyporhamphus meeki*, by Banford and Collette (1993). This species ranges north from the Gulf of Mexico, and is a rare stray into the Gulf of Maine. It usually can be distinguished from its southern relative, *Hyporhamphus unifasciatus*, by having a greater number of total gill rakers on the first (31 to 40) and second arches (20 to 30), and having a ratio of preorbital length to orbit diameter greater than 0.70 (Banford and Collette 1993). Contreras-Balderas et al. (1997) suggest the species can be distinguished using the shape of the lateral band. The specimen reported herein is unusual in having 29 gill rakers on right first arch and 23 gill rakers on the right second arch, both of which are low for this species. The identifying characteristic for this specimen is the ratio of preorbital length to orbit diameter, which equals to 0.74 (Bruce Collette, personal communication).

One previous record of *Hyporhamphus sp.* exists for eastern Canada. This specimen, reported as *Hyporhamphus unifasciatus*, was captured in a

herring weir at Chamcook, New Brunswick, on 30 September, 1949 (Leim and Day 1959). Its location suggests that this specimen may actually have been a *H. meeki*, a species that was not described at the time that this specimen was captured.

Dactylopterus volitans is a benthic species of fish that superficially resembles a searobin, and is typically found in tropical or warm temperature water. It ranges south to Argentina, and commonly is found as far north as North Carolina. The species occasionally strays north to Nova Scotia. Scott and Scott (1988) report four specimens from the Atlantic coast of Nova Scotia during the 1970s. The Nova Scotia Museum of Natural History has two records of *D. volitans* in Nova Scotia, both from the Atlantic Coast in 1990 (John Gilhen, personal communication). *D. volitans* have also been reported from the Grand Banks and Scotian Shelf (Lou VanGuelpen, personal communication).

Bluefish are regular summer visitors to the Bay of Fundy during warmer summers. The Fourbeard Rockling is a resident of the Bay of Fundy, and sometimes moves into embayments during summer and fall (Scott and Scott 1988). Water temperature was warmer and salinity was higher during early September in 1999 than during six previous years of sampling since 1985, perhaps leading to favourable conditions for these fish to move farther into the estuary.

The Meek's Halfbeak (reference number: ARC 0016423) and Flying Gurnard (reference number: ARC 0016422) are deposited at the Atlantic Reference Centre located at the Huntsman Marine Science Centre, St. Andrews, New Brunswick.

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Apparent Capture Myopathy in Hoary Bats, *Lasiurus cinereus*: A Cautionary Note

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Capture myopathy, a stress-induced disease resulting in metabolic acidosis, has not been recorded in bats. We observed two cases of apparent capture myopathy in Hoary Bats (*Lasiurus cinereus*) captured in mist-nets. We caution those intending to work with this species of a potential occurrence, and discuss capture protocols that may reduce the risk of capture myopathy.

Key Words: Hoary Bats, *Lasiurus cinereus*, capture myopathy, live-capture.

Biologists often rely on data obtained through live-capture. Live-capturing animals, however, may result in capture myopathy: a stress-induced disease, whereby the liberation of large amounts of lactic acid results in metabolic acidosis, which may lead to muscle necrosis and death (Chalmers and Barrett 1982; Pond and O'Gara 1994). Clinical signs of this condition may include muscle stiffness, loss of coordination, listlessness, and increased respiration and body temperatures, but affected animals can die without exhibiting outward symptoms (Chalmers and Barrett 1982). Capture myopathy can occur immediately upon capture or up to one month afterwards, and has been reported from a variety of species. To the best of our knowledge, there are no published reports of bats succumbing to capture myopathy. We encourage others to collate and disseminate their observations of capture myopathy in bats.

As part of a study on the habitat ecology of forest-dwelling bats in central Ontario (46.8° N; 81.9° W; Jung et al. 1999), bats were live-captured in mist-nets set across rivers and logging roads. On 4 August 1995 at 22:40 (EDT) an adult male Hoary Bat was captured. The bat was extracted from the net in < 5 min, and was active and vocal when captured. Once extracted from the net, the bat was placed in a home-made steel mesh holding container (Kunz and Kurta 1988), for about 25 min. After which the bat was discovered languid and did not fly. Therefore, it was placed on the limb of a small Trembling Aspen (*Populus tremuloides*), where it remained, suspended by its hind feet. The next morning the bat was discovered dead. Post-mortem examination indicated that the bat was in good condition, as the pelage was shiny, there were few noticeable ectoparasites, and its mass appeared normal (29.8 g.). Due to the difficulty in keeping the specimen frozen at a remote field camp, it was not sent for necropsy. We do not believe that the Hoary Bat was excessively handled, relative to > 100 *Myotis* spp. that we had captured. It is our belief that the Hoary Bat died as a result of the stress of being captured.

Similarly, as part of a study of the thermal ecology and foraging behavior of female Hoary Bats in southwestern Ontario (43.3° N; 81.8° W; Hickey and Fenton 1996), Hoary Bats were live-captured near street lights by swinging mist-nets at diving bats. On 8 June 1989, an adult female Hoary Bat was captured and banded. After about 10 min the bat was hand-released, but was listless and did not fly away. The bat was placed on the limb of a nearby tree and it remained there. The bat was checked daily and had not moved. On 12 June 1989, the bat was discovered dead, having apparently not moved since being captured. The bat did not appear injured, and seemed to have perished as a result of capture myopathy. In a related manner, our experience (MBCH) with Hoary Bats in captivity suggests that these species have a propensity to die within 1 month of capture, which may also be stress-related.

This is the first known report of apparent stress-induced capture myopathy in bats. We do not know why Hoary Bats may be more susceptible to capture myopathy than other bats such as *Myotis* spp. Although the prognosis is poor for individuals exhibiting signs of capture myopathy, Pond and O'Gara (1994) state that keeping the animal well-oxygenated and providing intravenous or subcutaneous administration of sodium bicarbonate in a saline solution is a recommended therapy. If stress-induced capture myopathy does occur somewhat regularly in Hoary Bats, then the use of a chemical immobilization agent

may reduce the likelihood of capture myopathy, through a reduction in the onset of extreme stress. Chemical tranquilizers have been used for small mammals (e.g., Wright 1983), but are not commonly used on bats. We recommend that Hoary Bats be processed as quickly as possible after live-capture, as they may not be as resilient to capture as other species of bats. We also suggest that steel mesh containers may provide substantially more oxygen than cloth bags, which are sometimes used to hold bats, thereby reducing the likelihood of capture myopathy. Bats that do perish after capture should be sent for necropsy to verify the cause of death.

Acknowledgments

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Mobbing Black-billed Magpie, *Pica hudsonia*, Killed by Cooper's Hawk, *Accipiter cooperii*

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Holroyd, Geoffrey L. 2002. Mobbing Black-billed Magpie, *Pica pica*, killed by Cooper's Hawk, *Accipiter cooperii*. Canadian Field-Naturalist 116(1): 137–138.

A Cooper's Hawk killed a Black-billed Magpie that was part of a group mobbing it. This occurrence happened before the breeding season. Any benefit of mobbing did not enhance the survival of this magpie.

Key Words: Black-billed Magpie, *Pica hudsonia*, Cooper's Hawk, *Accipiter cooperii*, mobbing, mortality.

Mobbing is the massing together of birds, often of different species, for the purpose of aggression and attack against a common predator (Terres 1982). Mobbing is most prevalent in the nesting season (Shedd 1982) but does occur year-round, particularly by species that remain on their nesting territory (Shedd 1983). This note documents an observation of a Cooper's Hawk (*Accipiter cooperii*) killing and eating a Black-billed Magpie (*Pica hudsonia*) that was one of a group that was mobbing it.

On 15 April 2000, just after 17:00 h, Phil Trefry drew our attention to a Cooper's Hawk on a White Birch (*Betula papyrifera*) in a low lying birch-willow (*Salix* spp.) bluff in a depression in front of his home about 50 km east of Edmonton (54° 24'N 112° 50'W). The farm is in rolling aspen parkland with open fields and Trembling Aspen (*Populus tremuloides*) and Balsam Poplar (*P. balsamifera*) dominated woods. The hawk was being mobbed by four magpies and two Blue Jays (*Cyanocitta cristata*). The mobbing was mostly "vocal approach" (sensu Shedd 1982) and flying at a distance. The mobbers did not fly at or strike the hawk. A Red-tailed Hawk (*Buteo jamaicensis*) was perched 50 m west of the Cooper's Hawk, higher in a birch tree, but was ignored by the corvids. One agitated magpie perched 1–2 m above the Cooper's Hawk in the same tree, calling and hopping ("mobbing" sensu Shedd 1982). The hawk glided to the ground under overhanging willow branches, 10 m to the south of its original perch. The magpie hopped to the ground about 3 m from the hawk where they were hidden from the observers by tall dead herbaceous vegetation. The hawk flew to the magpie, killed it and carried it along the edge of the bluff,

50 m north, then into the bluff behind some birch trees and out of sight. Over 10 magpies and two Blue Jays arrived from different directions and they and the other corvids called, hopped agitatedly and flew overhead. The Red-tailed Hawk and another that had been perched to the east, flew closer and perched nearby. After about 10 minutes the corvids and red-tails left. Three hours later we visited the two sites. At the kill site we could see the wing-tip prints of the Cooper's Hawk in the snow and two marks between the prints, presumably where the magpie had landed and died. At the northerly destination was a collection of magpie body feathers over an area of 3 sq. m, where the hawk had plucked part of the magpie. There were no flight feathers nor any of the magpie's carcass.

The purpose of mobbing is to drive a predator from a nearby nest or territory (Shedd 1982). Mobbing birds have been observed driving aerial predators to the ground or into the water (Terres 1982: 63, 627). However, mobbing does not always drive a predator from a nest (Taylor 1972). The present observation is unusual because the magpie was killed while mobbing and magpies are rarely preyed upon by raptors.

In April, Black-billed Magpies can be expected on territory. Although no magpies nested in the bluff where this observation took place, they are common breeding birds in the area (personal observation). Mobbing is more common in the breeding season in migratory species such as the American Robin (Shedd 1982), but occurs year-round with no apparent seasonality in non-migratory species such as Black-capped Chickadee (*Poecile atricapillus*) (Shedd 1983). The presumed advantage of mobbing to a bird without a nest is to drive the potential predator from the permanent territory of the bird. In our observation, the magpie did not have an active nest in the immediate vicinity to protect.

Sordahl (1990) reviewed 30 instances of predators killing mobbing birds. At least one of these instances involved a Cooper's Hawk (Wilson 1986). In 1962 in Virginia, R. D. Denson (1979) observed a Great Horned Owl (*Bubo virginianus*) kill one of a flock of American Crows (*Corvus brachyrhychos*) that were mobbing it. The owl grabbed the crow out of the air from its perch. As in our observation, the crow went too close to the owl. Although mobbing behaviour may drive away a predator, the close proximity of predator and potential prey can be expected to have some risk for the prey. In this case the magpie appeared to have made a mistake when it landed on the ground too near the hawk. The magpie was killed with little effort by the Cooper's Hawk as evidence by the lack of sign of a struggle in the snow.

Passerines mobbed Northern Harriers (*Circus cyaneus*) only when the harriers are in flight and actively hunting (Bildstein 1982). When the harriers are perched, the passerines ignore the hawks. In both our observation and that of Denson (1979) the Great Horned Owl and the Cooper's Hawk, species that will hunt from a perch, were mobbed while perched. The nearby perched red-tails, which are a known nest predator (Trost 1999), were not mobbed.

Magpies are rarely taken by raptors (Trost 1999). Three magpies were recorded in 550 prey remains collected at Peregrine Falcon (*Falco peregrinus*) nests (unpublished data) but none in 203 prey at Prairie Falcon (*F. mexicanus*) nests in southern Alberta (Hunt 1983). One Cooper's Hawk nest observed at nearby Beaverhill Lake did not include any magpie remains (unpublished data). Magpies were not reported in the diet of Cooper's Hawks in Washington and Oregon, which are within the magpie's range (Kennedy and Wilson 1986; Reynolds and Meslow 1984). Although this observation is only of a single event, the killing of a mobbing magpie by a Cooper's Hawk has interesting implications.

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Breeding Season of Wolves, *Canis lupus*, in Relation to Latitude

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A significant relationship was found between Wolf (*Canis lupus*) breeding dates and latitudes between 12° and 80° N, with Wolves breeding earlier at lower latitudes, probably because of differences in seasonality.

Key Words: Wolf, *Canis lupus*, reproduction, latitude, breeding, mating.

A general relationship between breeding dates in Wolves (*Canis lupus*) and latitudes from 41°–71°N was noticed by Mech (1970: 117) when he summarized published data from several locales. However, he conducted no statistical test of this hypothesis. Herein, I add data from other areas of latitude from 12° to 80° N (Table 1) and statistically test the effect of latitude.

I used latitude as the independent variable in a simple linear regression and the reported breeding date as the dependent variable. For breeding date, I used the mid date for the reported breeding season and converted all dates to sequential numbers starting with 15 October to facilitate comparing breeding dates before and after the start of the calendar year.

The relationship between breeding date and latitude was highly significant ($r^2 = 0.74$; $P < 0.0001$; $y = 16.19 + 2.23x$), supporting Mech's (1970) hypothesis. On average, breeding season shifts 22 days later with each 10° latitude increase. It seems reasonable to suggest that the shift is related to differences in general seasonality and thus in associated ecological conditions.

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TABLE 1. Mating seasons of wolves at various latitudes.

Location	N Latitude	Season	Authority
Southern India	12°	October	Kumar and Rahmani 2001
Arizona[a]	34°	February, March	W. Brown, personal communication
Illinois[a]	42°	February	Rabb 1968
Yellowstone National Park[b]	45°	February	Smith et al. 1998
Ontario	47°	Early March	Joslin 1966
North Dakota	46°–49°	January	Bailey 1926
Isle Royale (Michigan)	47°	Late February	Mech 1966
Minnesota	48°	February	Mech and Knick 1978; Fritts and Mech 1981; Fuller 1989
British Columbia	51°–53°	March	Cowan 1947
Germany[a]	52°	Mid March	Schonberner 1965
Alberta	60°	February, March	Soper 1942; Fuller and Novakowski 1955
Northwest Territories	60°–65°	Late March	Kelsall 1960
Alaska	60°–71°	March	Murie 1944; Kelly 1954; Rausch 1967;, Lentfer and Sanders 1973; Mech et al. 1998
Finland	60°–70	March	Pulliainen 1965
Russia	71°	Late March–early April	Makridin 1962
Ellesmere Island	80°	Late March-early April	Mech 1993

[a]Captive wolves
[b]Wolves translocated from 53–56° N.

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Canada and the "Buffalo", *Bison bison*: A Tale of Two Herds

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From 1907 to 1912 the Canadian government purchased and imported more than 700 plains Bison, *Bison bison*, from Michel Pablo in Montana. A new national park, with an area of 159 square miles was established near Wainwright, Alberta, to accommodate them. It has generally been acknowledged that Buffalo National Park played an important role in saving the Plains Bison from extinction. This paper makes use of a packet of government files that were saved from destruction during the early1940s. The files deal mainly with events from 1912 to 1925, including the first appearance of bovine tuberculosis, and later the prevalence of tuberculosis in the herd. They also contain notes from the meetings of senior civil servants that led to the decision to transfer diseased plains bison to Wood Buffalo National Park, as well as summaries of submissions of those opposed to the transfer. One option, to slaughter the entire herd and start over with disease-free stock, was rejected by well-meaning members of the public. When the Buffalo National Park was turned over to the military in 1940, 17 000 bison had been slaughtered as a result of annual culling. Ironically, had a total slaughter been carried out in 1923, fewer than 7 000 would have been killed. In addition, it is probable that we would have pure Wood Bison and no tuberculosis in Wood Buffalo National Park. In 1963, 18 disease-free Bison derived from a group of animals that showed some of the characteristics of Wood Bison, were released in the Mackenzie Bison Sanctuary. That herd now numbers about 2 600 individuals. As in 1923 we again have two herds, one with a high prevalence of tuberculosis and a second that is disease-free. In 1990 an Environment Panel (1990) recommended total depopulation of Wood Buffalo National Park and restocking with disease-free animals. As in 1923 the recommendation to slaughter and restock met opposition on several fronts and so far no action has been taken. Must we repeat the serious error made in 1923?

Key Words: Wainwright, Bison, tuberculosis, brucellosis, Pablo, slaughters, cattalo, transfer.

More than thirty years ago I received from Dr. C. H. Douglas Clarke (see tribute and bibliography by Lumsden 1984a, 1984b) a box of old federal government files that were related to the origin and subsequent operation of the Buffalo National Park near Wainwright, Alberta, and the transfer of Bison from there to Wood Buffalo National Park. According to a letter that accompanied the files, they were "...salvaged from the wartime file disposal in Ottawa." Clarke gave as his reason for saving the files from destruction that "I realized that it was a personal record, kept by the late Maxwell Graham, to show that for his part he did his best to prevent the transfer of buffalo from Wainwright to the Wood Buffalo Park, and to promote herd reduction by slaughter."

Maxwell Graham was Director of Animals in the Dominion Parks Branch of the Department of the Interior from January 1912 until his transfer to a different Branch on 1 January 1922. The files shed light on his role as guardian of the Bison in the Buffalo National Park near Wainwright, Alberta. At one time, those buffalo were much in the news, and some of the material in the files would have been "hot stuff" politically. Clarke wrote: "Poor old Graham was in an uncomfortable spot, and I have a feeling of personal obligation towards him." By accepting the files, I assumed that obligation, which I am only now attempting to fulfill.

This paper will reveal information that has not been made public until now about the management of Buffalo National Park and about the transfer of buffaloes to the newly created Wood Buffalo National Park. My belief is that lessons learned so long ago are pertinent to the current situation in Wood Buffalo National Park. My hope is that those lessons will be taken to heart by all who have an interest in the long-term welfare of the buffalo.The files are the source of all direct citations set in small type and inset paragraphs.

Plains Buffalo

1. Disappearance from the wild

When Europeans first reached the great central plain of North America they were greeted by immense herds of "buffalo", whose Latin name is *Bison bison*. Bison is now the approved common name for the beast, and I will use it from this point on. As time wore on and the human population increased, the Bison population decreased. The story of their decline has been told by several observers, such as Allen (1875), Hornaday (1889) and Isenberg (2000) for the United States; Hewitt (1921), Roe (1951) and Foster (1992) for Canada. Around the middle of the 19th century so many Bison had been killed that those remaining were essentially confined to two herds that were referred to as "southern" and "northern." The southern herd was wiped out during the 1870s, and the northern herd followed in the 1880s. Fortunately, a number of ranchers, in both the United States and Canada, had captured and raised a

few Bison. One such herd is referred to either as the Allard, or the Pablo, herd. That herd was in Montana, conveniently close to Canada.

2. Recovery in Buffalo National Park

After a considerable amount of negotiation, the Canadian government reached an agreement in 1907 with the owners of the Pablo herd to purchase a few hundred bison at $200 per head. They were to be delivered to a new park close to Wainwright, Alberta. However, the first shipment arrived before the fencing and buildings were finished in the new park, and the animals had to be released in Elk Island National Park, which had been set aside for the preservation of "elk" (American Elk, *Cervus elaphus*) in 1904.

When Pablo began rounding up his animals, he discovered that he had more than the few hundred bison that Canada had originally contracted for. On 11 June 1907, 199 head arrived at Lamont, Alberta, the rail station nearest to Elk Island National Park. On 11 October, another shipment of 211 head arrived at Lamont. No shipments were made during 1908 owing to illness on the part of Pablo, and the escape of 120 animals ready for transfer, but, during that year 73 miles (116 km) of fencing was put in place, and construction of other facilities was completed at the new Buffalo National Park. In May of 1909, 325 of the Bison originally sent to Elk Island were recaptured and moved to the new park. The remainder of the 410 animals originally delivered in 1907, estimated to be only 48 head after the transfer in 1909 to Wainwright, formed the basis of the herd that still occupies part of Elk Island National Park. Later that year, Pablo delivered 218 head to Wainwright. In 1910, he was able to deliver 74 animals and he made two shipments of seven bison each in 1912. In total, he was paid for 716 bison, 631 of which ended up in the Buffalo National Park. An additional 77 animals came from Banff National Park in 1909, and 30 came from the Conrad herd, which was also in Montana.

According to one of the old files, the total number of animals introduced to the park was 738, but there is no record of the number of deaths or births during the years 1909 to 1911. Initially, the park, in total, occupied 159 square miles (a little more than 400 square km). Later, more land was acquired on which to grow hay for winter feed. Experts in the Department of Agriculture estimated that its carrying capacity was about 7000 bison.

3. Events at Buffalo National Park

Rate of Growth in Numbers

I have been unable to find a complete set of annual census Figures, either in the old files or other sources, but I found nine numbers for the years 1911 to 1923 inclusive. (Table 1). Counts were apparently made in some, but not all years.

Populations not under restraint tend to increase exponentially. A few hundred animals on a new range planned to support 7000 should be free of restraint. One of the properties of an exponential series is that the natural logarithms of the numbers lie on a straight line. The equation for the $\log_e$ transformed data is $LN(Nt) = 4.562 + 0.192\ t$ where $LN(Nt)$ is the natural logarithm of the number of Bison "t" years after their introduction to the Park; 4.562 is the logarithm of the number of Bison introduced to the park at time $t = 0$; and 0.192 (19.2%) is the annual rate of increase in numbers. The r^2 for this equation is 0.995.

Entrapment of other species

When the initial perimeter fencing was completed, park personnel discovered that they had enclosed wild elk, Mule Deer, *Odocoileus hemionus*, Moose, *Alces alces*, and a few Pronghorn Antelope, *Antilocapra americana* (Lothian 1981: 29). I was suspicious about the antelope, but their presence was verified by Rowan (1929: 359). Apart from competing with Bison for the available forage, there was a slight chance that the ungulates could have acquired diseases from contact with domestic cattle before they were trapped. In 1939, 1806 elk, 113 moose, and 242 deer that had been sharing the range with the Bison were slaughtered. Six per cent of the Moose and two individual deer "showed evidence of tuberculosis" (Lothian, 1981:37).

Cross Breeding Experiments

For several years The Department of Agriculture had followed the experiments of a Mr. Mossom Boyd in Ontario. Boyd had crossed Bison bulls with domestic cows and got fertile, hybrid offspring. The first generation hybrid offspring, when mated, also gave fertile offspring, which were named "Catalo" from the first three letters of "cattle" and last three letters of "buffalo." The name was later changed to "Cattalo." When Mr. Boyd died, the Department of Agriculture obtained his experimental animals and shipped them to an Agricultural Station at Scott, Saskatchewan. The agricultural scientists, anxious to do further experiments, entered into negotiations

TABLE 1. Available Counts of Bison in Buffalo National Park, 1911 to 1923.

Year	1911	1912	1913	1914	1915	1916	1919	1921	1923
Count	738	994	1188	1453	1640	2077	3830	5052	6780

with the Dominion Parks Branch to obtain some Bison and space in Buffalo National Park so they could conduct more experiments in cross-breeding.

At this point, Maxwell Graham, Director of Animals in the Dominion Parks Branch, enters the story. The salvaged files contain a memorandum from Graham to Mr. J. B. Harkin, Commissioner of National Parks, dated 27th June 1916. Graham reminded Harkin that they had discussed the question of cross-breeding "prior to my departure for the west ... but the whole question was left in abeyance till Department of Agriculture was ready to take definite action." He went on to write:

> I was only made aware the other day that such action had been verbally undertaken during my last absence from Ottawa, and subsequent action in confirmation thereof through correspondence has only now been brought to my attention.
>
> I am only now aware that it is proposed that a portion of Buffalo Park, about six square miles, be fenced off for the purpose of keeping therein the Cattalo herd bought by the Department of Agriculture from the estate of the late Mr. Mossom Boyd;
>
> That the shipment of these animals took place on or about November 26th last from Bobcaygeon Ontario, to Scott Saskatchewan;
>
> That certain other bovines, being cows of the Galloway breed, are also to be imported, I believe from the east, and to be added to the Cattalo herd for experimental purposes.
>
> I now desire to point out that if such action is taken, the herd of bison, now over 2000 in number at Buffalo Park, will incur considerable additional risk of becoming infected with some variety of infectious disease.

Graham admitted that there was already "a certain risk to be faced of some infectious disease obtaining a lodgement in our main herd" but he pointed out that most of the land around the park was under cultivation and such land carries on it "but very few cattle of any kind." He then expressed his fear that:

> We shall certainly run considerable risk, however, if we actually introduce into the park cattle in any quantity from Ontario. Some of these animals may, though themselves immune, be carriers of disease from other herds.
>
> I would also point out that when an infectious disease is once brought into a large herd, the losses become very high, because it is difficult, if not impossible to check it after it has once obtained a foothold.

He then went on to mention several such diseases — Hemorrhagic Septicemia. Anthrax, Foot and Mouth Disease — all of which had recently been discovered in the west.

Finally, he most strongly recommended, in the same memorandum, that "some other area be found for the cross-breeding experiments... an area with natural drainage, and good running water and springs" instead of the "low land, stagnant water and liability to recurrent flooding of considerable areas" in Buffalo National Park.

The Director of Agricultural Experimental Farms, J. H. Grisdale, lost no time in replying. His response is dated 5th July 1916 and required a little over three sheets of legal paper. His comments are in blue type, and the whole is peppered by comments in red type initialed M. G. (Maxwell Graham). The most important point comes near the end of Grisdale's letter.

> I may conclude my remarks with respect to Mr. Graham's memorandum by saying that after having perused it most carefully, and after having discussed it with the Veterinary Director General, with the Pathologist of the Department of Agriculture, each of whom assures me that, with average precaution, the probabilities of any infectious diseases being transmitted to your buffalo through the proximity of the herd of cattalo are practically negligible.

Graham's response to that paragraph was directed to his own superiors.

> This, I consider completely absolves us from any possible future criticism. Dr. Gordon Hewitt and myself each independently considered an added risk to be incurred & that is all I have contended. (signed) M.G.

So the Bison, cattle, and cattalo of the Agriculture Department were established on 6 square miles of park land. Only a single fence, which permitted nose to nose contact, separated them from the Bison herd. Later, they were joined by several Yaks (*Bos mutus*). Grisdale guaranteed that all animals would be tested for diseases before being released inside the cattalo pen. Did any infectious diseases come with the experimental animals? We will never know for sure, but Graham was to raise the question again several years later.

The cattalo episode did raise other questions. In a six-page (legal size) memo dated 7th July 1916 Graham reviewed the precautions already taken since 1912 and what was still needed. He made it plain that a major requirement was some means of segregating individuals by means of a system of corrals and cross fences. He had first made that request in 1914, but his request was turned down in a letter from Head Office to the Superintendent of Buffalo Park, dated 19th December 1914. The letter stated simply that "[T]he expense of constructing further fenced subdivisions would appear to be out of the question at present." He fared no better in 1916.

First Indications of disease

The threat of disease was always a major concern for Graham because of his position as Chief of the Animal Division. His immediate superior, to whom he reported, was J. B. Harkin, Commissioner of Dominion Parks. There are a number of lengthy memoranda among the files from Graham to Harkin, urging that action be taken to reduce the risk of a serious disease outbreak. Virtually all of his pleading, such as the need for a system of corrals cited above, fell on deaf ears.

It was almost 1917 before the first case of tuberculosis was discovered. On 20 December 1916 a *post mortem* inspection of a dead bull revealed

lesions typical of tuberculosis. In January 1917 a visual inspection of the herd was ordered. Help was received from an inspector from The Agriculture Department. Out of the herd of 2 000+, only two or three animals were judged to be in poor condition. They were segregated from the main herd, but apparently not tested or slaughtered and examined *post mortem*.

Veterinary Inspector Gillam wrote to Graham and recommended an enclosure with corral and a squeeze chute, "which would prove useful should it at any time be deemed advisable to vaccinate against Blackleg, Anthrax, or Contagious Abortion." (The last of these is also known as Brucellosis.) No corral, let alone a squeeze chute, was forthcoming.

No confirmed new case of tuberculosis showed up until 20 March 1919 when a dead cow was found, examined by the local Veterinarian, and diagnosed as having died from tuberculosis. The cow was thought to be about 15 years old.

On 22 April 1919, a 4-year-old bull was killed and a *post mortem* examination revealed "traces of T.B."

On 13 April 1920, "an apparently healthy buffalo bull selected for slaughter for the Hudson's Bay Company banquet, was found to be tubercular."

In spite of the evidence cited above, the Deputy Minister of the Department of Interior denied, in an interview published by the Montreal Gazette for 2 December 1922, that there was any tuberculosis in Buffalo National Park.

Incontrovertible Evidence of Disease

The first slaughter of Bison at Buffalo Park took place in February 1923, when 264 Bison were killed, butchered, and examined by a dominion veterinary inspector. Dr. A. E. Cameron (later the Veterinary Inspector General) and Dr. Seymour Hadwen, then of the Ontario Research Foundation, were also present. Cameron (1923) published a small paper entitled "Notes on Buffalo: Anatomy, Pathological Conditions, and Parasites" without even mentioning tuberculosis. Hadwen withheld publication of his observations until 1942.

No details about disease are in the files that I have, but Lothian (1981: 32) wrote that "The inspectors found that 75 percent of the animals slaughtered (in 1923) had some form of tuberculosis lesion." He did not mention, though, that the sample was strongly biased toward old males and thus was probably not representative of the herd as a whole.

Lothian goes on to say (Page 32): "Dr. Hadwen recommended the elimination of the herd to avoid the spread of infection, but the proposal was not acceptable to park authorities." The following winter, 1923–24, 1847 bison were killed, but there is no record in the files of the occurrence of any disease. Dr. A. E. Cameron (1924) published a second paper entitled "Some Further Notes on Buffalo" In which he disposed of tuberculosis in a single sentence on the last page: "Tuberculosis has been found in buffalo, as is common in wild animals in captivity."

Lothian's only comment was (page 32): "The presence of disease was withheld from public knowledge as a matter of departmental policy." Apparently it was still a matter of departmental policy in 1981 when Lothian's book was published.

Instead of informing the public about the health of the herd, the government distributed pamphlets containing recipes for preparation and cooking of buffalo meat, whether from healthy or diseased animals.

When Graham, who had transferred from the Parks Branch to the Northwest Territories and Yukon Branch at the beginning of 1922, learned the results of the slaughter he wrote a memorandum dated 13 April 1923 to W.W. Corry, Deputy Minister, Department of the Interior. It was marked "Personal and Confidential." The pertinent points raised by Graham, with my comments in square brackets, were the following:

> As the official particularly charged with the administration of the buffalo in National Parks from January 1912 to January 1st, 1922, I am naturally concerned to hear that as a result of investigations made by Dr. Seymour Hadwen, he has reported the herd at Buffalo Park as being seriously infected with Tuberculosis
>
> I am fully aware that under the circumstances, once Dr. Hadwen's report is made public, I, as former Director of Park Animals, must expect considerable criticism. Knowing as I do, and as our records will plainly show, that every effort to prevent such a calamity has consistently and all along been made by me, I personally do not fear such criticism.
>
> But the loss of your confidence in me I should feel very keenly, and in order to forestall such I wish to bring to your attention the following facts.
>
> 1st. During my tenure of office, so far as I am aware, there have only been four cases of tuberculosis, definitely so pronounced, in Buffalo Park. [The four cases already noted above.]
>
> 2nd. During the slaughter of surplus buffalo in September 1922, Doctor Hadwen I understand, reports lesions in organs examined from the condition of which he estimated that not more than six years could have elapsed since infection took place. And, so I understand, infection in most cases was of a more recent date.
>
> 3rd. Our records will show that as far back as 1914, I strongly recommended that the Buffalo in Buffalo Park should be allowed to freely range during winter, instead of being confined in "winter quarters", and I stated "The danger of infectious or contagious diseases attacking the herd would not be as great (if allowed to winter in the main park) as if the herd were all kept together in confined quarters" (or confined feeding area.)
>
> My recommendation was turned down, without being referred to you, and it was not till July 1917 on the advice of Doctor Hargrave, Chief Inspector for Alberta, that action was taken to carry out my recommendation of 1914.
>
> I would suggest that Doctor Hadwen, as an unbiased authority, might be asked his opinion on the points

raised in my memorandum of June 27th, 1916, and whether or not in his opinion the recommendations made in my memorandum re tuberculosis of March 19th, 1919 were sound.

In any case, these latter were not acted on except in so far as reference is made to them in the attached memorandum of April 1st, 1919 by Doctor Torrance.

The part of Dr. Torrance's letter to which he refers seems to be the following:

The whole question is one of providing plenty of nourishment and fresh air. The buffalo, I understand, are constantly out in the open, and they should always be provided with an abundance of nutritive food so that they may be maintained in as vigorous a condition as possible.

The next, and last, point raised by Graham must be read in association with his 2nd point.

It only remains to be added that my attempt in 1916 to prevent what I then considered, and still consider, an uncalled for additional risk to the buffalo...was met with by unmerited censure and ridicule.

When in September 1922 Doctor Hadwen made his investigation of the herd in Buffalo Park, just six years had elapsed since, against my protest, the cattalo and domestic bovines were first placed in Buffalo Park.

Graham is clearly making a connection between arrival of the Bison, cattle, and yaks in 1916 and Dr. Hadwen's finding that none of the cases of tuberculosis were older than 6 years, i.e. acquired no earlier than 1916. He does not go quite so far as to make an outright accusation.

Without, however, actually blaming the cattalo and domestic bovines in the experimental herd for the serious condition of our buffalo in Buffalo Park, it would seem that my modest expression of opinion as to the added risk incurred by insistence in selecting the place for cattalo experiments where it is was fully justified.

Written in pencil across the upper left hand corner of the first page of the memorandum is the following:

"Mr. Graham, I don't see how you can be blamed in this matter. W.W.C." The initials are those of W. W. Cory, Esq., C.M.G., Deputy Minister, Department of the Interior, to whom the memorandum was addressed.

There is also a short memorandum directed to Mr. Graham and signed by O. S. Finnie, Commissioner of the Northwest Territories and Yukon Branch, Department of the Interior, to which Graham now belonged. It read:

I read over, with much interest, the correspondence hereunder. The evidence shows conclusively that you always entertained apprehensions as to the safety of the herd at Wainwright — even in the face of expressions to the contrary from those in high authority. They cannot lay at your door the charge that you failed to advise them of the dangers of disease.

I interpret this to be, on the part of the government at least, a clear exoneration of Maxwell Graham.

The Horns of a Dilemma

Even before1920, the relentless pressure of exponential increase in the size of the herd, coupled with deterioration of the range, created a serious problem for Buffalo Park managers on the site, senior civil servants in Ottawa, and ultimately, elected politicians. Something had to be done — but what? The only options appeared to be to continue with annual slaughters, or slaughter of the entire herd, or transfer the surplus to some other suitable location.

Hewitt (1921: 136), whose book was published posthumously, had some further suggestions. One was to "establish small parks in other parts of the Prairie Provinces, where small herds could be maintained, which would make the bison accessible to people". He suggested also (136) "[E]very large city should have its zoological park." And finally he set out his view on the possibility of domestication.

"The greatest value of the buffalo, however, lies in the possibility of its domestication... the greatest need of the prairie provinces is an increase in its beef-producing capacity. The buffalo is an animal which offers great possibilities, being pre-eminently suited to prairie conditions, and at the same time it produces a robe of no small commercial value" (136). At the time when this was written, no one seemed to take domestication seriously, and disease did not seem to be a barrier. Today, in North America, there are many more Bison on private ranches than in parks and reserves.

When the slaughter of nearly 2000 bison in 1923 was made public there was a strong reaction against further slaughters. Given the strong public objection to a simple herd reduction, the Parks Branch felt that total elimination of the Buffalo National Park herd, as suggested by Hadwen, was out of the question. Dr. C. H. D. Clarke, who salvaged the files, was also in favour of total slaughter and restocking with healthy Bison from Elk Island National Park.

Wood Bison

In January 1772 Samuel Hearne and his Indian companions crossed Great Slave Lake from north to south. Hearne (1795: 250) wrote: "Immediately on our arrival on the south side of the Athapuscow [now Great Slave] Lake, the scene was agreeably altered, from an entire jumble of rocks and hills, for such is all the land on the North side, to a fine level country, in which there was not a hill to be seen, or a stone to be found." As they made their way up the lowlands on the eastern side of the Slave River, he noted that "Buffalo, moose, and beaver were very plentiful...." Hearne (1795: 251) also noted that "The buffalo in those parts, I think, are in general much larger than the English black cattle: particularly the bulls, which, though they may not in reality be taller than the largest size of the English oxen, yet to me always appeared to be much larger. In fact, they are so heavy, that when six or eight Indians are in company at the skinning of a large bull, they never attempt to turn it over while entire, but when the upper side is

skinned, they cut off the leg and shoulder, rip up the belly, take out all the intestines, cut off the head, and make it as light as possible, before they turn it to skin the under side. ....The head of an old bull is of great size and weight indeed: some which I have seen were so large, that I could not without difficulty lift them from the ground." Hearne was thus the first European to see and describe the wood buffalo.

When I was at Fort Smith in the 1940s and 1950s I took part in the skinning of many a Bison, and I watched many Indians and Métis working in pairs. I never saw them lighten the load before turning over a Bison in Wood Buffalo National Park.

Hearne was not usually given to exaggeration, as were many explorers of his day, so I take his observations as evidence that the Wood Bison were considerably larger than those of the plains.

Other early explorers saw Wood Buffalo in the course of their journeys. While visiting Forts Chipewyan and Wedderburn, on Lake Athabasca, Captain John Franklin (1823:154) noted that "The traders here also get supplied by the hunters with buffalo and moose deer meat (which animals are found at some distance from the forts)..."

After descending the upper Slave River, and negotiating the rapids above the present Fort Smith, Franklin ascended the Salt River as far as the salt springs, where his men collected salt for the rest of their journey. On leaving the springs (Page 107) they "perceived a buffalo plunge into the river before us." The unfortunate animal was immediately shot and kept the entire crew in meat until they reached Fort Resolution on Great Slave Lake. While there he was informed (199) that the residents "Procure moose, buffalo, and rein-deer meat occasionally from their hunters; but these animals are generally found at the distance of several days' walk from the forts."

Joseph Sabine, a zoologist of Franklin's time, prepared The Zoological Appendix (Number V), to Franklin's narrative. About the *Bos Americanus* or American Buffalo, he wrote (1923: 688) "... they are extremely numerous on the plains of Sashatchawan,(sic) and are also found, though less plentifully, in the woods as far north as Great Slave Lake; a few frequent Slave Point, on the north side of the lake, but this is the most northern situation in which they were observed by Captain Franklin's party."

The reference to Slave Point, on the *north* side of the lake, has been cited by several other authors, who, apparently, did not verify its location. Slave Point was said to be composed of limestone. The only Slave Point on modern maps is at approximately 61° 10' N and 115° 55' W on what I would call the west shore rather than the north shore. No Slave Point appears on Franklin's map on the true north shore which, in any case is composed of Precambrian granites, not flat limestone.

In the middle of February 1890, Warburton Pike (1892: 143) set out from Fort Resolution on a buffalo hunt with an Indian guide named François. His assessment of the distribution of bison was as follows:

"Scattered over this huge extent of country are still a few bands of buffalo. Sometimes they are heard of at Forts Smith and Vermillion, sometimes at Fort St. John close up to the big mountains on Peace River, and occasionally at Fort Nelson on the north branch of the Liard."

After reaching the end of François' road, and walking until noon, they came on a band of eight bison and killed one cow. A few weeks later he made a second hunt, again with François as his guide, but they saw no trace of bison. Pike (1892: 43) appears to have been the first to attribute the size of the wood buffalo to environmental factors as the following quotation shows:

"These animals go by the name of wood buffalo and most people are of opinion that they are a distinct race from the old prairie buffalo so numerous in bygone days; but I am inclined to think that the *very slight difference in appearance is easily accounted for by climatic influences, variety of food, and the better shelter of the woods*." The italicized words are one of the untested hypotheses that will play an important role in what happened later.

In 1892, Frank Russell, a young academic at the University of Iowa, began his journey into the far north. On 9 January 1893, Russell set out from Fort Resolution, guided by François who had guided Pike. As Pike had done, he began his journey on the Little Buffalo River and later turned off to the southwest. On the fourth day they reached what he called (Russell, 1898: 103). "the northern limit of the buffalo range, perhaps fifty miles south of the Great Slave Lake." They saw no buffaloes and had to return empty handed after 13 days on the trail.

Early in the spring of 1902, Charles Camsell was asked to search the country south and west of Fort Smith for Wood Bison. At that time he was a very junior member of the Geological Survey, which was in the Department of the Interior. Before he retired, at age 70, he had risen to Deputy Minister of the Department of Mines. His journey is set out in his memoirs, Camsell (1954). He and his assistant launched their canoe at Athabaska Landing (now Athabasca) and paddled down to Smith Landing (now Fort Fitzgerald). From there they went by ox cart to Fort Smith. From Fort Smith, they made two short sorties and saw only one small bison herd and many tracks. Their final trip took them to the Peace River by way of the Salt River, the upper Little Buffalo, and the Jackfish River. They began that journey on 2 August and reached the Peace a whole month later. Camsell estimated that the number of Wood Bison was probably about 300, but he gave no data of any kind to support his estimate.

Ernest Thompson Seton and Edward A. Preble set out for the north, by canoe, in 1907. Seton could not have chosen a better companion than Preble who, with his brother, covered about 1200 miles by canoe in the Hudson Bay region in 1900, and in 1903–04 travelled several hundred more miles in the Athabaska-Mackenzie Region.

En route to the tundra, Seton and Preble paused at Fort Smith for a buffalo hunt. Their guide led them to a group of 13 bison the first day (page 48) and 22 the second day (page 52). An account of Seton's trip was published in 1911 (Seton 1911) and republished in 1943.

It is apparent from this brief survey that Bison lived at least as far north as the south shore of Great Slave Lake and perhaps further. It is also apparent that by the end of the 19th century, their numbers were rather small, and the largest herd was thought to live in the angle formed by the junction of the Peace and Slave Rivers.

Maxwell Graham visited the area south of Fort Smith in 1912. On his return to Ottawa he wrote a memorandum, dated 16th October 1912 to J. B. Harkin. He dealt briefly with the character of the country through which bison ranged, the length of time that they are known to have lived in the region, and the size and type of "these pure-blood bison." He argued that although ample range is critical for their survival, ample range alone is not enough. They also need other kinds of protection. Graham suggested that protection would be easier and less expensive if the various small groups of bison could be herded into a single reserve. He felt that the ideal location for such a reserve was the junction of the Peace and Slave Rivers (Figure 1). He noted that:

> A line drawn eastwards from Peace Pt. upon the Peace River, would intersect the Great Slave River about 20 miles below the junction with the Peace. If a suitable fence were constructed along this line, a distance of 25–30 miles, the Buffaloes could gradually be worked from the North into this peninsula where there would be ample range for a number of years.

Graham thought that "herders" could turn back any Bison that sought to cross the Slave or the Peace River in winter over the ice, but he neglected the possibility of escape by swimming across the rivers in summer, which Bison do with ease.

Graham also quoted from what he called the "Smithsonian report." (See Hornaday 1889).

> "There is reason to fear that unless the government takes the matter in hand and makes a special effort to prevent it, the pure-blood bison will be lost irretrievably through mixture with domestic breeds, and through in-breeding; this latter causes eventually, loss in size and final sterility.... As I have already stated no suitable stock can now be procured from any of the herds in the United States, a large number of these are not pure-blood, some which are, have deteriorated in size owing to too close confinement and in-breeding,"

That most of the herds in the United States are not pure-blood has recently been confirmed by mitochondrial DNA sequencing (Polziehn, et al., 1995.)

Graham's memorandum closes with the following paragraph.

> Such being the case I again urge that the future administration of this Northern Canadian Herd, the last and best of the buffalo, be entrusted to this Dominion Parks Branch, and that provision be made in the estimates to provide for the enclosure proposed above, a plan of which is appended herewith and that a vigorous policy as to this herd's protection be instituted, and a capable superintendent be appointed who shall have the interests of this Branch at heart, and who would also understand and appreciate the policy of the Dominion Parks Branch."

No action was taken on Graham's memorandum. The need for a reserve of some kind was raised again in 1914 at a meeting of the Council of the Northwest Territories, which met in Ottawa in those days, but again it was not acted upon.

Camsell made three more short trips into the Wood Bison range during the summer of 1916 at the request of the Parks Branch of the Interior Department. A type-written copy of his report is among the salvaged files. On page 1 Camsell wrote:

> The wood bison of northern Alberta and the adjacent portion of the Northwest Territories are in *two separate bands occupying two distinct ranges, and there does not seem to be at present or within recent years any migration of buffalo from one range to the other*.... A belt of muskeg country 30 to 40 miles wide separates the northern from the southern range and prevents migration from one herd to the other except by way of the Salt plain.

The italicized portion is the second untested hypothesis that was to play a role later on.

The second important conclusion in Camsell's report is that most of the Wood Bison were in an area extending from the Peace River north to latitude 65° (clearly a typographical error) between longitudes 112° and 113°. On page 5 he suggests a game reserve bounded by 60° on the north, 113° 20' on the west, latitude 59° 10' on the south, and Slave River on the east. No action was taken on his recommendation for a reserve. In 1918, another recommendation to create a park was also turned down.

In 1922, Maxwell Graham revisited the range of the Wood Bison. His report, entitled "Some observations on the wild buffalo in Northern Alberta and the Fort Smith District, Northwest Territories," fills 5 sheets of legal paper and is dated 23 November 1922. The report begins with a notation that "true buffalo" are found only in Africa and Asia, and that the "buffaloes" of Europe and North America are properly known as "bison." There is only one species of Bison in Europe, *Bison bonasus*. There is also only one species in North America, *Bison bison*, which was thought by many to have two subspecies.

Graham wrote:

> Both the writer and his colleague are in a position to state that our Northern wood-buffalo are larger, darker, and handsomer specimens than those which formerly ranged the plains far to the south.

He goes on to say, however, that:

> in the writers'(sic) opinion, whatever differences there are between it and those of the plains, is (sic) entirely owing to environment.

Graham clearly agreed with Pike's untested hypothesis. It is not clear whether or not Graham believed that Wood Bison would revert to Plains Bison if they were moved to central Alberta, or conversely, Plains Bison would come to resemble Wood Bison once they were moved to the wood bison environment. On page 2 of the memorandum Graham wrote:

> The buffalo at Elk Island Park are supposed, in the aggregate, to be the best in any park, nevertheless, without meaning to disparage this fine herd, the writer and others who were with him on the wood-buffalo range must state that in size, thriftiness, stamina and general appearance the wild wood-buffalo is in a class by itself and quite unapproachable.

The use of "in a class by itself" suggests that they were worth preserving whether or not they were formally recognised as a subspecies.

Graham made his headquarters at Pine Lake in 1922. A wagon road connected Ft. Smith and Pine Lake. About two miles before it reached the lake, the trail crossed the upper Salt River. When I worked in WBNP in the late 1940s, the old trail and the crossing were still visible and I visited the old crossing, and saw the tree in which Graham had a platform from which to watch Bison. One of the first "buffalo rangers," Billy McNeil, was my informant.

Here are some excerpts from notes Graham made on August 12, 1922.

> The most successful day yet. Dull and raining in the morning, but clearing towards noon. Stewart and I started (on foot) for Salt River Crossing. At Wallows on the way I spotted a huge bull lying down, however, he winded us and got away before we could get a picture. On arrival at Salt River Crossing, Stewart climbed a leaning tree and I posted myself across the river under a small tamarac,(sic) in full view of open muskeg. We saw and got pictures first of a herd of 16 buffalo. In about half an hour another herd of about the same size came out of the forest, of which we also got some pictures. Stewart followed these in hopes of getting some close-ups, none of them having seen or scented us...Shortly after, Stewart returned not being able to catch up the buffalo in the bush beyond river (sic), and it was then that I heard more coming... So far as I could estimate there were 9 in this herd, one immense bull, two cows, two 2 year olds, 3 yearlings and 1 very small calf, whose skin was throughout of a faint yellowish white colour.

All in all, Graham and his assistant saw and counted 114 bison, which was more than all other visitors mentioned above had seen. He also ventured to estimate the total number. His estimate was based upon

> ...the finding of old trails and old wallows being reopened as well as the presence of new ones, and from the number of young stock seen it is safe to state that the wood-buffalo are increasing, and from all the evidence our party was able to investigate, at a conservative estimate, the number of buffalo in the southern range may be put down as 1000.

Graham also argued again for more protection from poachers, forest fires, and Wolves (*Canis lupus*), in the form of an enlarged corps of rangers (now wardens). The last paragraph in the report suggests that Graham had some inside information.

> Both for the protection of the buffalo as well as valuable forms of other wild life, it is expected that steps will shortly be taken to conserve for posterity the range on which the buffalo roams.

Another memorandum dated 13th November 1922 is entitled "Reasons Why the Wood Buffalo of Northern Alberta and Northwest Territories should be preserved."

> These buffalo are the last of their species living to-day under absolutely free and wild conditions.
>
> They are the finest specimens of their species, superior in pelage, size, and vigour to those of the plains, whose descendants to-day exist in our parks.
>
> Owing to certain physiological causes buffalo in captivity deteriorate in size and stamina, further, when in confinement their natural increase contains an undue proportion of males to females, which unless steps are taken to remedy this surplusage (sic) of males is apt to bring about tuberculosis and kindred diseases.

We know now that sex is determined by presence or absence of a Y chromosome, and it is not clear how the sex ratio is involved in the spread of disease.

> The time is approaching when an infusion of new, unrelated, blood will be needed by our herds in the National parks, and it is only from the northern herd that such infusion can be obtained.
>
> Looking to the future success of the experimental cross-breeding between buffalo and domestic bovines, it is imperative that a reserve stock of pure blood bison of the highest potency should be kept in reserve, so that the ultimate fixed type of new range animal may continue to pass on to successive generations the prepotent qualities of the true bison, viz hardiness, thriftiness, a valuable robe and first class beef qualities.

A second typescript is also among the files. It may be a draft of "Canada's Wild Buffalo," which was published by the Department of Interior in 1923. It contains more information than the memorandum about the nature of the country, such as meadows, muskegs, sloughs, poplar ridges with edible grasses, jack pine ridges that have a scanty ground flora, and sink-holes that develop in the gypsum that underlies much of the area.

Associated with the report and manuscript was a letter, dated 22 November 1922, to Graham from R. M. Anderson, who was then Chief, Division of Biology, Victoria Memorial Museum. His letter reads, in part, as follows.

FIGURE 1. Maxwell Graham's original map showing the area he proposed as a reserve for wood buffalo in the angle between the Peace River, which comes in from the southwest, and the Slave River which exists to the north. The line near the top is the 60th parallel. The grey patches in the lower right are water bodies.

I have carefully read over the manuscript of your description of the wood buffalo range, observations on the habits of the wood buffalo, and reasons why the wood buffalo of northern Alberta and Northwest Territories should be protected. It is very interesting as a very up-to-date summary of the wood buffalo situation as well as a comparison of the wood buffalo with the more southern herds, and there is really nothing that I can criticize in the paper.

The desirability of keeping a reserve stock of pure

blood buffalo, living under free, natural conditions, is so obvious as to need no argument....

Thanking you for your kindness in loaning me the report, I remain

Yours sincerely,

(signed) R. M. ANDERSON

About one month after Graham submitted his reports, the steps that he had predicted came to pass. An Order in Council established Wood Buffalo National Park (WBNP) in December 1922. The stage was now set for the two streams we have been following to come together. Suddenly, 10 500 square miles of sparsely populated wood bison range became available to receive the excess in the National Park at Wainwright.

The Transfer Goes Ahead

The following information is taken from a document assembled by Col. J. P. Richards dated 6th May 1923. Col. Richards held a senior position in the Department when I joined it in 1947, and I found him to be an honest, dedicated public servant. The title of the document is "Summary of correspondence dealing with the transfer of the buffalo from Wainwright to Wood Buffalo Park." Notations in square brackets are my comments.

1. The decision makers

Under date of 23rd May, 1923, the Commissioner of Canadian National Parks advised the Department that there were too many buffalo in Wainwright Park and some arrangement would have to be made to reduce the number.

The Department suggested that instead of slaughtering excess buffalo it might be desirable to transfer some of the healthy [?] young stock to the Wood Buffalo Park and it was arranged to call a conference to discuss the proposal. The conference was held on the 30th May and the following extracts which are taken from a memorandum dated 5th June, 1923, outline the decisions arrived at.

Under date of May 30th. 1923, on Wednesday at 3 p.m. a conference was held at the Commissioner's office, at which were present Mr. W. W. Cory, acting in a dual capacity as Deputy Minister of the Department and Commissioner of the Northwest Territories, Mr. O. S. Finnie, Director of the Northwest Territories, Mr. J. B. Harkin, Commisssioner of National Parks, Doctor F. Torrance, Veterinary Director General, Department of Agriculture, and Mr. A. Smith, Superintendent of the Wainwright Park.

It is important to note that Maxwell Graham's name is absent from the list of participants. He took no part in that conference.

The question before the Conference was concerned with the disposal of buffalo surplus to the capacity of the Wainwright Park, and also the advisability of introducing these surplus buffalo into the Wood Buffalo Reserve.

The question was rendered more complex owing to the fact that *tuberculosis had manifested itself among the buffalo in the Wainwright Park.* [My emphasis]

The conference was opened by the Deputy Minister's statement that Mr. Harkin had informed him something must be done to relieve the growing congestion of buffalo at the Wainwright Park, that the slaughter of a large number of buffalo had been suggested, but he disliked the idea of such slaughter and had thought a way out of the difficulty could be found by transplanting the surplus Wainwright buffalo into a new environment away from all danger of communicable disease. [Except what they took with them, of course.]

Such an area was to be found in that area selected by the buffalo themselves, whose descendants are now known as wood buffalo and whose habitat near Fort Smith has recently been created a park. Addressing in particular Doctor F. Torrance, the Deputy Minister requested his opinion with respect to the chances of recovery from tuberculosis if buffalo infected with this disease were transplanted in the Fort Smith district, and if in his opinion there would be any serious menace to the wood buffalo through such action being taken.

Doctor Torrance was of the opinion that although in some less advanced cases an improvement might be looked for, the transplantation of any considerable number of the infected herd into the range of one, presumably, not infected would be extremely hazardous.

It was then finally decided that selected young stock, not over one year old, should as soon as possible, be segregated, corralled, and squeeze-chuted, in order that each one might be subjected to the intradermal test. Those passing the test to be shipped by rail to Peace River Crossing, thence by scows, through the [Vermilion] chutes, to Peace Point and liberated in the Wood Buffalo Reserve. [Peace Point is an outcrop of limestone at least 15 metres high!]

Dr. F. Torrance of the Department of Agriculture, who was present at the conference, expressed his opinion about the disease problem in a letter to the Department on the 30th of the same month.

As regards Tuberculosis, the suggestion has been made that some of the younger buffalo should be transported to the range of the wood buffalo in the north and permitted to mingle with them. This proposition is objectionable from a health point of view, in that *it would be almost certain to carry infection to this herd of wood buffalo*, which presumably is at present free from this disease. [My emphasis]

If this proposition were, however, modified and preparation made so that young animals up to the age of yearlings only were transferred, and that these animals were, previous to transference, submitted to the tuberculin test, so as to eliminate any that reacted, much of the objection would be removed.

Note that Torrance did not give his outright blessing to use of the tuberculin test. As late as the 1950s at least, the tuberculin test gave some false negatives so Dr. Torrance would have known that a single test would not have detected all reactors.

Under date of the 13th November, 1923, the Edmonton Journal published a despatch from Ottawa in which it was stated that the Minister of the Interior had announced that it was the intention to transport two thousand buffalo calves from Wainwright to Wood Buffalo Park.

A second Parks Branch Memorandum dated 20th November, 1923, dealt only with the steps to be taken to prevent injury to the animals in transit from Wainwright to WBNP. The Commissioner, Canadian National Parks Branch, on the 22nd of the month, commented upon the memorandum referred to in part as follows:

> There is one subject which has been discussed in the department which is not mentioned in Mr. Nagle's memorandum, that is the possibility of the transfer of Wainwright buffalo to the wood buffalo range resulting in the introduction of tuberculosis in the wild herd. You will remember that last spring we had a conference with Dr. Torrance upon this subject and that the Doctor would not commit himself concerning this aspect of the situation.

A letter dated 27 November 1923 from J. B. Harkin to Edmund Seymour, President of the American Bison Society was published in the Report of the American Bison Society for 1922–23 page 32. It read as follows:

> "Since last winter the Department has had under consideration a proposal to make shipments of buffalo from the surplus of the Wainwright herd to Fort Smith country, now occupied by the so-called wood bison. It is the intention of the department to make some experimental shipments next Spring but I doubt very much whether the number will be as large as one thousand. Difficulties in connection with the transportation of adult buffalo to such a remote area are so great that it is improbable that any attempt will be made to send adults to the north. Yearlings appear to be the only type that could be handled on such a project. Just what number will be sent has not been decided. I do not think a decision can be reached until next spring. The only established fact in connection with this subject is that the Department's present intention is to make an experimental shipment."

Nowhere does the summary of discussions on movement of Bison mention an "experimental shipment." So why did Harkin write the letter? It could have been to alert Seymour with the hope that he would protest the shipment in the name of the Bison Society. It is even possible that Maxwell Graham drafted the letter for Harkin's signature. The copy of the Bison Report for 1922–23 that arrived with the files has Graham's name and departmental address on the cover.

There followed a copy of a report by an Inspector Waddy on the prevalence of tuberculosis in 46 bison. According to the file that lists all slaughters from 1923 to 1937 there was "no slaughter" in 1924–25, but a copy of the report, dated 10th Jan'y 1924, was sent to the Veterinary Director General, and a copy is among the salvaged files. The report begins with an arbitrary, but adequate, definition of three age classes. The definitions are as follows:

> With not more than one pair of permanent teeth up — under 5 years
>
> With all permanent teeth up but not worn at the edge — 5–10 years
>
> With all teeth in wear — over 10 years.

TABLE 2. Prevalence of tuberculosis in a sample of 46 bison examined by Dr. Waddy in January, 1924.

Age Class	Number Slaughtered	Number Positive	Percentage Positive
1	15	2	13.3
2	13	9	69.2
3	18	16	88.9
TOTAL	46	27	58.7

Table 2 shows Dr. Waddy's findings.

Waddy remarked "I think this plainly shows the prevalency of generalized T.B. in the old animals."

The numbers certainly speak for themselves. Prevalence increases with the age of the animal, and more than half of the animals in the sample were infected with tuberculosis. The findings also help to explain the high incidence of tuberculosis in the 1923 slaughter that was biased toward old males. The Richards memorandum went on as follows:

> This report was received in the Department at the time consideration was being given to the proposal to transfer a number of Wainwright Buffalo to Wood Buffalo Park. *It will be observed that fifteen animals five years of age and younger were examined by Inspector Waddy and only two showed slight evidence of tuberculosis.* No animals over the age of three years were transferred to Wood Buffalo Park and the number of three-year olds that accompanied the shipment was less than five per cent of the total.
>
> At a conference held in the Deputy Minister's office on the 9th April, 1924, it was decided to transport 500 yearling buffalo from Wainwright to Wood Buffalo Park during the summer of 1924. It was decided that the Parks Branch would assume responsibility for segregating, corralling and squeeze chuting and placing the buffalo in cars at Wainwright, that the Northwest Territories Branch would be responsible for the care and transfer of the buffalo from Wainwright to Waterways, thence by barge to Wood Buffalo Park. This arrangement was concurred in by the Minister under date of 24th April, 1924.
>
> Instructions respecting the shipment of the buffalo were received by the Superintendent at Wainwright too late to permit of the young buffalo being segregated in time for shipment in 1924 and it was decided not to attempt to transfer any buffalo until the following year. The Superintendent of Wainwright Park was given instruction to make plans for the transfer of at least two thousand young buffalo in 1925. [Note that it is now "young" buffalo, not yearlings.]
>
> In [a] memorandum dated 6th October, 1924, the Commissioner of the Canadian National Parks refers to a conference which was held in the Deputy Minister's office on the 3rd idem when the following decisions with respect to the transfer of the buffalo from Wainwright to Wood Buffalo Park were made:
>
> 1. In 1925 at least two thousand buffalo would be shipped.
>
> 2. The shipment would include only one-and-two-year old animals from the 1923 and 1924 increase.
>
> 3. *That the tubercular test would be dispensed with.* [My emphasis]

4. That the responsibility of the Canadian National Parks Branch would cease when the animals were loaded on the cars at Wainwright.

If we take the Waddy report at face value, that is two tubercular animals out of every 15, then around 900 of the 6673 animals delivered would have been carrying tuberculosis.

The actual ages and numbers transferred over the next four years are shown in Table 3.

Another column in the file listed deaths en route, which totalled 47 animals accidentally crushed or injured. None of the reported deaths "were attributed to tuberculosis." The next sentence, however, reads: "The carcasses were not examined to ascertain whether the animals were infected, since there was no government official available qualified to make such an examination."

My home in Fort Smith in 1947 was no more than 100 m from the home of an elderly gentleman who had been the Chief Warden of Wood Buffalo National Park when the transfers were made. He told me that many animals died as they walked down the gangplank at the landing, or as they made their way along a trail that ran for about 2 miles from the river through some woods to the nearest patch of prairie. Other old timers at Fort Smith, who had taken part in the unloading, confirmed the Chief Warden's story. When I mentioned this conversation in a letter to Ottawa in 1947 I got a reply that said in no uncertain terms that 6673 animals were delivered, apart from 47 that died en route. Apparently, the translocation was still a touchy subject 20 years after it happened.

The next paragraph in the Richards memo lists the names of several people who were opposed to the venture. Another document lists arguments pro and con.

2. Controversy about the translocation

Two things that caused the most concern among opponents of the transfer were first, that infectious disease might be introduced to the Wood Bison, and second, the Wood Bison would disappear as a subspecies through hybridization with the introduced plains bison.

Those who defended the transfer based their arguments mainly on three untested hypotheses. First came Camsell's claim that the northern and the southern herds of Wood Bison were separated by a band of marsh and muskeg that could not be crossed. Thus, regardless of what happened to the southern herd, the northern herd would not hybridize and it would not be exposed to disease. Second came Pike's belief, supported by Graham and others, that any differences between plains and Wood Bison were superficial and due to environmental factors. Some supporters of this view went so far as to predict that the introduced animals would gradually develop the characteristics of Wood Bison. Third, the introduced animals were too young to carry any infectious disease including tuberculosis. Both J. B. Harkin and Dr. Torrance, however, expressed concern after the rejection of Dr. Torrance's recommendation, that only yearlings that passed a tuberculin test were to be shipped.

Among the defenders was Maxwell Graham, even though he was no longer associated with the Dominion Parks Branch. In a one page Letter to the Editor of *The Canadian Field-Naturalist* (Graham 1924) he upheld Camsell's belief in the barrier between northern and southern herds, and the belief that the difference between plains and Wood Buffalo was just a matter of different environments. I believe that he genuinely believed that the transfer "will be the means of saving for posterity the calf crop at the Wainwright Park for 1922–23 and succeeding years."

Mr. Edmund Seymour, President of the American Bison Association, and Dr. W. T. Hornaday, an American mammalogist, met with the Deputy Minister. The stance taken by the Bison Association would have carried considerable weight among the general public. However, the Deputy Minister persuaded Seymour and Hornaday to give their approval to the actions taken by the government. The warning they received in Harkin's letter, if it really was a warning in disguise, was ignored.

On the other hand, a considerable list of people, many of them well versed in mammalogy, expressed their objections directly to the government or through published articles.

Dr. D. Rutherford, Department of Agriculture, University of Saskatchewan, told the Minister in a letter that the transfer was a mistake.

W. E. Saunders (1925), a naturalist living in London Ontario, wrote "it would be better to lose the entire Wainwright herd, rather than risk the last remnant of the Wood Buffalo."

TABLE 3. Numbers and Ages of Bison Transported from Wainwright to Wood Buffalo Park in the Years 1925 to 1928.

Season	Yearlings	Two Years	Three Years	Total
1925	1127	507	-	1634
1926	1435	493	83	2011
1927	1255	436	249	1940
1928	1009	79	-	1088
TOTAL	4826	1515	332	6673

Professor A. B. Howell, Chairman of the American Society of Mammalogists, cited a resolution passed at their Annual Meeting condemning the transfer because "distinctive characteristics of the Wood Buffalo would be lost in a few generations," and "TB and other diseases would be likely to be transmitted with harmful effects to the northern herd."

Dr. Francis Harper (1925: 45), an American mammalogist who had travelled from Lake Athabasca to Great Slave Lake with Charles Camsell, and who had visited the Park in 1920, made a number of points in a letter to the Editor of *The Canadian Field-Naturalist*. First, "The wood buffalo (*Bison bison athabascae*) is too important an animal to be subjected to experimentation that may result in decided harm to the entire subspecies." Second, "The proposal outlined by Graham raises the old question of man's interference with nature, which, in too many cases is alike unnecessary and unjustifiable." Third, "Establishment of the Park was one of the most important and far-sighted conservation measures ever adopted by the Dominion Government." The implication is why spoil it? Fourth, with respect to the separation of the northern and southern herds he wrote "This gap can hardly yet be accepted as a proven fact, or as a necessarily permanent condition. There is evidently no physical barrier that would prevent the two herds from mixing." Fifth, "The possible transmission of disease through the introduced plains buffaloes is another factor to be considered." Sixth, if the Wainwrights cannot be settled in Alberta, "would it not be wiser to send them to the slaughter-house at once?"

Two members of the National Parks Branch faced censure over publication of Harper's critical letter to the editor. One was Mr. Hoyes Lloyd, Supervisor of Wildlife Protection, who was also President of the Ottawa Field Naturalist Club at the time. The club's journal was, and still is, *The Canadian Field Naturalist*. The Editor of the journal was Dr. Harrison F. Lewis, who later became the first Director of the Canadian Wildlife Service. For publishing Harper's letter, both men were required to vacate their position in the Club, or face dismissal from the civil service. According to Lothian (1981: 34), Lloyd had already written a memorandum to Commissioner Harkin in which he called the decision to ship animals from a herd known to be infected to a herd that had never had contact with the disease, "very bad epidemiology," and "the biologically correct way of dealing with the excess buffalo is to slaughter the excess, thus realizing on the surplus stock."

Professor William Rowan of the University of Alberta visited the Park in 1925 and collected two specimens of Wood Buffalo under permit. He published an account of his trip in "Country Life." A typescript of part two of his article is included in the salvaged files. In his final paragraph he wrote "I need not discuss the pros and cons of the proposal here, suffice it to say that it called forth, naturally enough, the most vigorous protests from scientific quarters from all over Canada, from the States and even from England." Rowan was black-listed by the Department of the Interior as a result.

Other condemnations appeared in the two most important scientific journals in the world. Dr. Ritchie, in England, published his objections in *Nature*. Perhaps the most serious condemnation came from Dr. Thomas Barbour, Director of the Museum of Comparatives Zoology at Harvard University,Boston. In a book review published in *Science* for 25th November 1932, he referred to the transfer of bison as follows:

> This, one of the most tragic examples of bureaucratic stupidity in all history, was done against the protests of both Canadian and American naturalists who would rather have seen the surplus bison killed. They were known to be infected with bovine tuberculosis and they are certain to interbreed as well as infect the wood bison, which is a far finer animal and one of great zoological interest because in some respects it seems more like the European wisent than the common American Bison.

3. The Aftermath

Wainwright

Transplanting a reasonably large number of Bison each year did not solve the overpopulation problem in Buffalo National Park. As early as the winter of 1926–27 more or less regular slaughters were resumed. There is an accounting of the number of Bison killed, and a meticulous record of the money received for the sale of Bison products, but there is no mention of the prevalence of any disease or parasite in the records I have. Table 4 lists the years, and the numbers of Bison killed.

Dr. Seymour Hadwen attended many, but not all of the slaughters. The data for Figure 2 come from Hadwen (1942). Numbers killed are shown on the bars. They are Hadwen's numbers and some of them differ slightly from the government numbers in Table 4.

Hadwen suggested that the prevalence may have declined over time. An alternative explanation is that

TABLE 4. Number of Bison Slaughtered at Wainwright After Transfers Began.

Year	1926-1927	1927-1928	1929-1930	1930-1931	1931-1932	1932-1933	1933-1934	1934-1935	1936-1937	1937-1938	1939	Total
Number	2001	1000	525	47	1534	1220	2000	1000	1522	3246	2918	17013

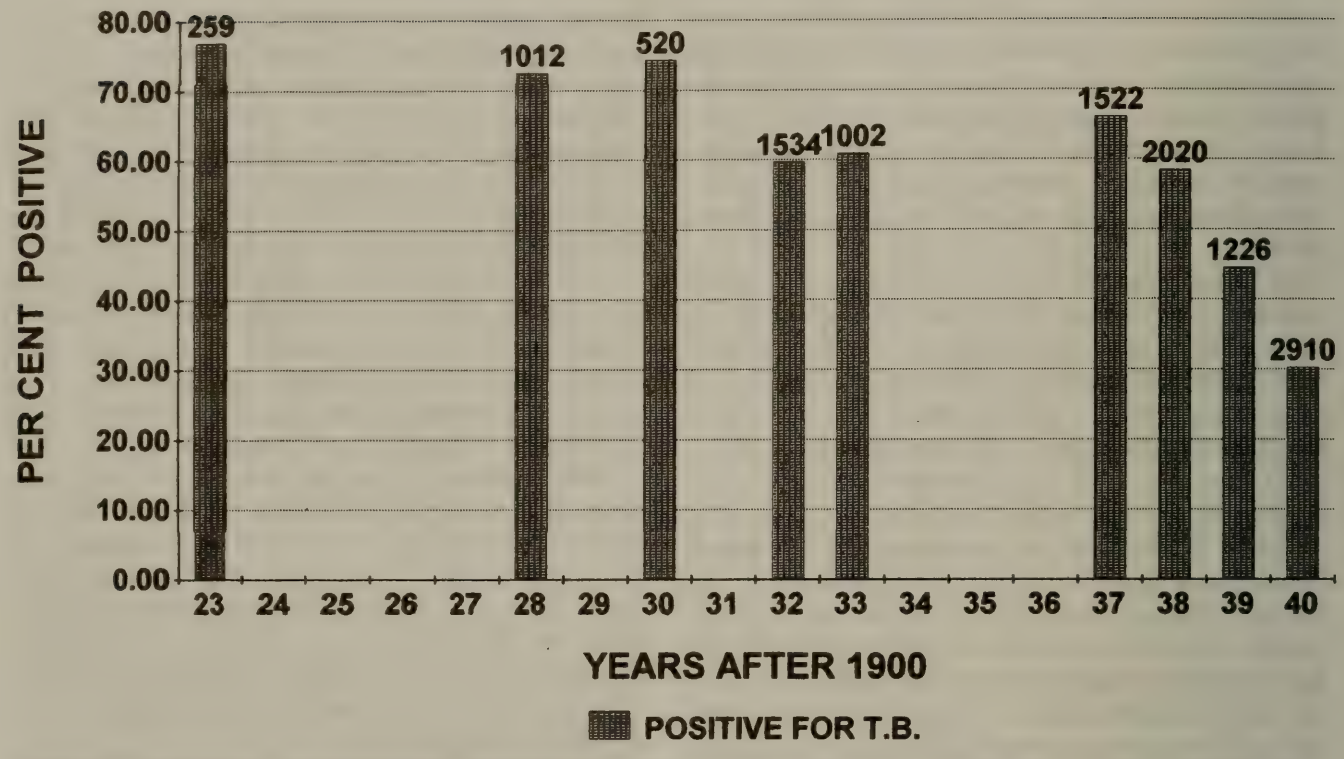

FIGURE 2. Prevalence of tuberculosis in bison at Wainwright (After Hadwen (1942). Numbers over bars are sample sizes.

the early slaughters concentrated on the oldest animals, which were most likely to be positive for tuberculosis (Table 2). We know that was true for the sample in 1923. It was probably true for 1928 and 1930, because all three of those years had a prevalency rate greater than 70%. If so, as the proportion of old animals in the slaughters declined, so would the prevalence of tuberculosis.

Wood Buffalo National Park

Population: The Wainwright bison were unloaded either at the Hay Camp, located on the west bank of the Slave River about 50 km upstream from Fort Fitzgerald, or at Buffalo Landing, which was about midway between Hay Camp and Fort Fitzgerald. Some accounts mention La Butte as a destination, but it is on the east bank of the river, which is not in WBNP. Park employees at the time of the introduction of the Plains Bison noted that the residents and the newcomers mingled almost at once. That does not mean, however, that there was a great deal of breeding, either with each other, or with the resident Wood Bison, in the year of their arrival. Two thirds of the total were yearlings, and less than 5% of female bison breed as yearlings (Fuller 1962: 21).

The first attempt to make a census of the Bison in WBNP was made in 1931 by the Royal Canadian Air Force. They set out to cover the entire winter range and take photographs of all herds of Bison. Something went wrong because they photographed fewer than 2 400 Bison.

J. Dewey Soper was sent to WBNP in 1932, where he stayed until 1934 studying the fauna, especially the Bison. He was limited to surface travel — canoe and pack horses in summer; dog sled and snowshoes in winter. Soper did his best to estimate what the numbers might be. His best guess was 12 000, which is within the realm of reality.

In 1947, Mr. E. G. Oldham, Superintendent of Forests and Wildlife, attempted an aerial survey. Instead of attempting full coverage he flew strips so placed that he covered one third of the area of the park. He counted 2494 bison so his estimate was 7482 in the park as a whole. Details of his census were in a file at Fort Smith when I arrived there in 1947.

In 1949, I made an aerial strip count based on 25% coverage (Fuller 1950). My estimate was not less than 10 000 or more than 12 500. In a repeat aerial census in 1951 (unpublished) I got essentially the same result, which suggests that the population was not growing, but staying more or less constant. All of that came to an end after 1970.

In 1969 the flow of water in the Peace River was cut off near its source when the gates were closed on a new dam and the water was held back to fill a reservoir. The flow was "restored" after the reservoir was filled. That is to say, about the same amount of water comes down the river in a year, but the seasonal distribution of the flow is altered. Spring floods are essentially a thing of the past. Without spring floods every few years the Peace Delta has undergone radical change. Perched lakes go dry; what used to be navigable small streams running into Lake Clair are choked with vegetation; sedges are being replaced by grass, and grass by shrubs and trees. All of this has had an enormous effect on the number of Bison in the part of WBNP south of Peace River (Figure 3).

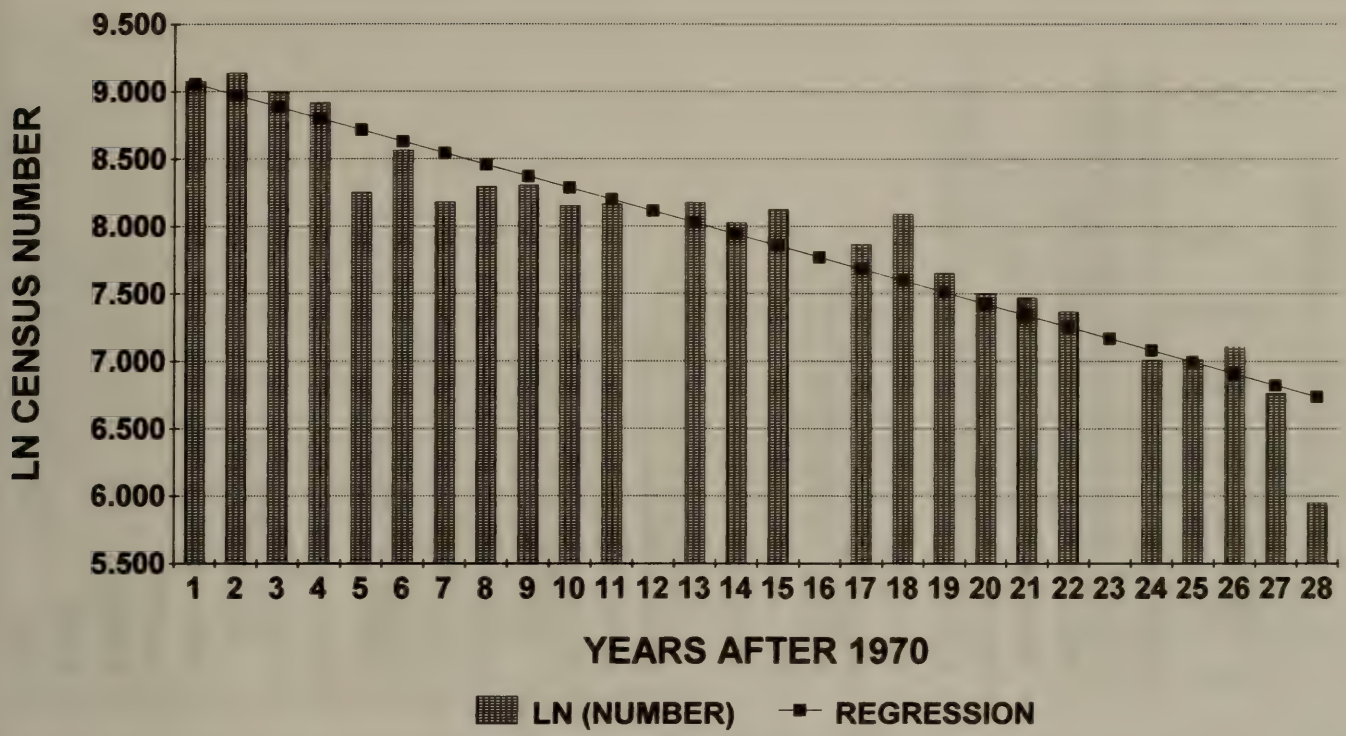

FIGURE 3. Natural logarithms of counts of bison south of Peace River beginning in 1971. The straight line is the Calculated Regression Line.

The equation for the regression line for the $\log_e$ transformed numbers is: LN(Nt) = 9.141 – 0.086t, with an r^2 of 0.887. The rate of decline over 28 years has been 8.6% per year, and the probability that the relationship could have occurred by chance is less than 0.001.

Figure 4 shows what has happened to the population as a whole. The striking similarity between these two Figures shows that changes in the delta have affected not only the southern part of the park but the park as a whole.

The equation for this $\log_e$ transformed regression is LN(Nt) = 9.137–0.051t, with an r^2 of 0.917. The overall rate of decline has been 5.1% per year. The probability that the relationship was due to chance is less than 0.001.

North of Peace River the population fluctuated up and down without any visible pattern. The regression line, which actually has a positive slope of 0.5%, is meaningless, with an $r^2 < 0.001$.

Tuberculosis: Col. Richards ended his summary of correspondence concerning the transfer with two short, but interesting, paragraphs.

> The information available lends support to the view that as only young animals were being transferred to the Wood Buffalo Park, improvement in their condition might be looked for. It is doubtful whether any of our park officials are in a position to definitely determine to what extent the animals in Wood Buffalo Park are affected with tuberculosis. In these circumstances it would seem that facts are not available to justify the conclusion that tuberculosis is prevalent or endangering the buffalo in Wood Buffalo Park.
>
> It is the practice to authorize the killing of a number of aged buffalo in Wood Buffalo Park each year, the meat of which is distributed to charitable institutions and to natives and half-breeds in the northern districts. In view of Mr. Soper's report it would seem that the services of a veterinarian should be available at the time of the buffalo slaughter to ensure that the meat of healthy animals only is being disposed of for the purposes mentioned.

When I arrived in Fort Smith in 1947 the term was 'buffalo hunt' not slaughter. The hunt began in the fall after it got cold enough to preserve the meat. Old males were the targets even though it had been known since the 1923 slaughter at Wainwright that the prevalence of tuberculosis was highest in aged animals, especially males. Park staff did all the shooting. Skinning, butchering, and transporting were the responsibility of the recipients. The Fort Smith hunt took place on the Salt Plains, which could be reached by 4-wheel drive vehicles. The Fort Chipewyan hunt took place on part of the Peace-Athabasca Delta where the only means of transportation was the dog sled, and the whole crew slept in a two-room cabin.

In 1950 a professional butcher and a veterinary meat inspector were brought from Edmonton for the hunt at Fort Smith. I worked with the veterinarian, who showed me where to look for signs of tuberculosis, and what the signs are. I carried on as "inspector" for the animals killed at Chipewyan. Thus ended about 25 years of feeding uninspected carcasses to school children and people on welfare.

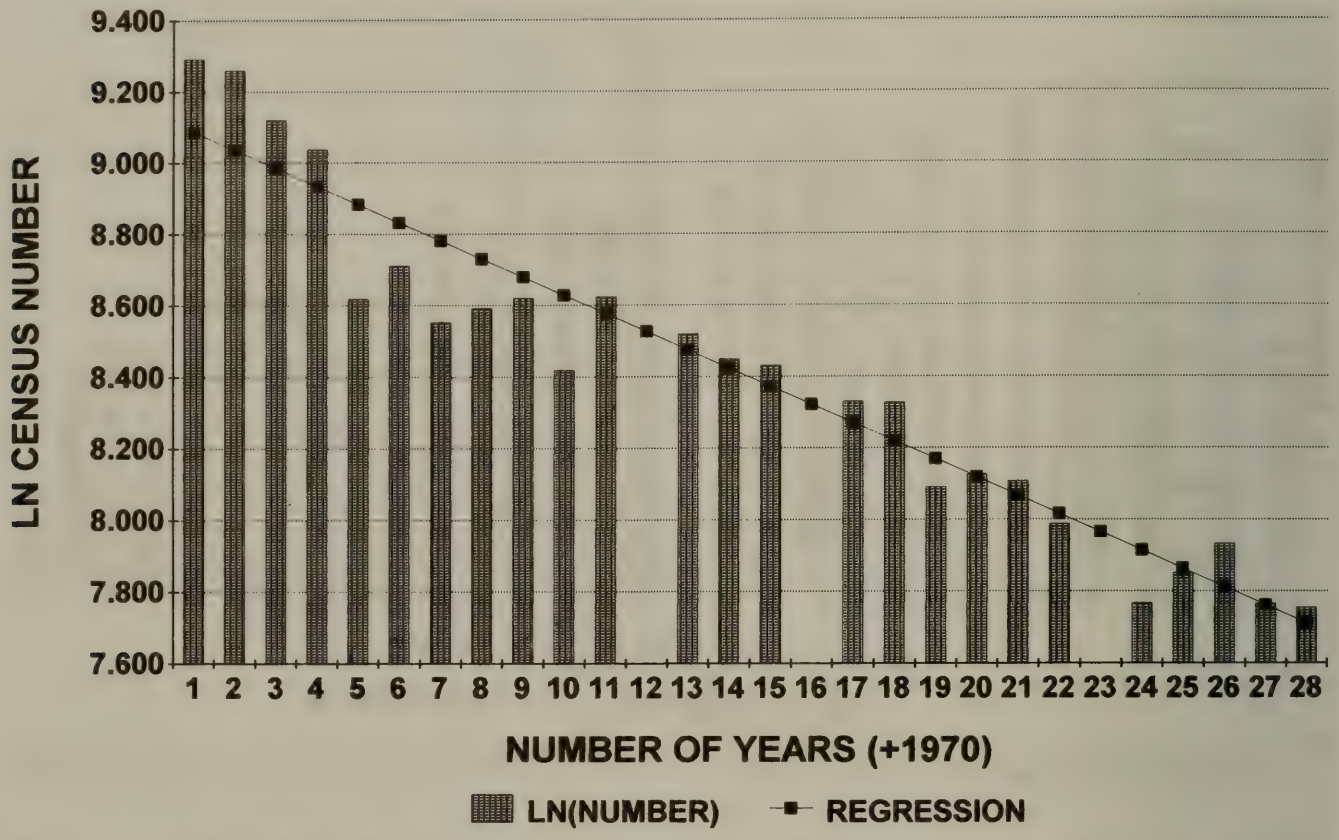

FIGURE 4. Natural logarithms of counts of bison in Wood Buffalo National Park as a whole beginning in 1971. The straight line is the Calculated Regression Line.

For two or three years a mobile "abattoir" was used. It consisted of three buildings on sleds pulled by a tractor. Finally, permanent abattoirs were constructed at Hay Camp and on the Peace Delta close to Sweetgrass River. A Veterinarian was present at all slaughters once the abattoirs were in use.

As an example of the findings, Figure 5 shows the prevalence of tuberculosis in 527 males and 981 females examined at Hay Camp in the years 1952–56 (Fuller 1962: 29). Age Class 0 means calf, Classes 1 to 4 are ages 1 year to 4 years, Class 5 is Young Adult, Class 6 is Prime Adult, and Class 7 is Old Age. Characteristics used to define each age class are set out in Fuller (1959).

It is clear from Figure 5 that the prevalence of tuberculosis increased with age as it did at Wainwright. Almost three-quarters of adult and old males were positive. Overall, 38 per cent of males and 40 per cent of females showed evidence of tuberculosis. There can be no denying that tuberculosis had been introduced to Bison in WBNP.

Brucellosis (Contagious Abortion): The origin of Brucellosis in the park is a mystery, but it is most likely to be the Wainwright animals. Brucellosis was first confirmed in the park in 1956, which was the year that I left Ft. Smith. Some symptoms characteristic of Brucellosis had been seen during slaughters, but laboratory confirmation was lacking because it had not been possible to keep samples from freezing in the camps and on their way to the lab. The prevalence of Brucellosis at the Sweetgrass abattoir during its period of use (1957–1958 to 1973–1974) was 39.5%. A total of 1681 individuals were sampled of which 664 were positive.

The incidence of tuberculosis at Hay Camp during the same period was 31%. Given these two results, the probability that an animal chosen randomly did not have at least one of the two diseases was 0.417 or about 4 chances out of 10.

Recent studies of Bison diseases were reported by Dr. Stacey Tessaro (1989) and Tessaro et al. (1990). Tessaro (1989:5) found "...brucellosis in 18 (25%), and tuberculosis in 15 (21%), of 72 Bison that had died as result of hunting activity, wolf predation, natural accidents, or disease. The combined prevalence of the two diseases in the sample was 42%. Of the 56 Bison that were killed, butchered and utilized by native hunters, 24 (43%) had one or both of these two zoonotic diseases. Three or four Bison seen killed by wolves were severely debilitated by generalized tuberculosis, and I suspect that a significant portion of the adult Bison mortality attributed to Wolves is predisposed by disease. Another cow was found to have died of pulmonary tuberculosis. Brucellar arthritis in three Bison resulted in crippling, emaciation and death of these animals. Eight other severely lame and emaciated bison were seen in the park, but these animals could not be collected for scientific evaluation." Tessaro also expressed

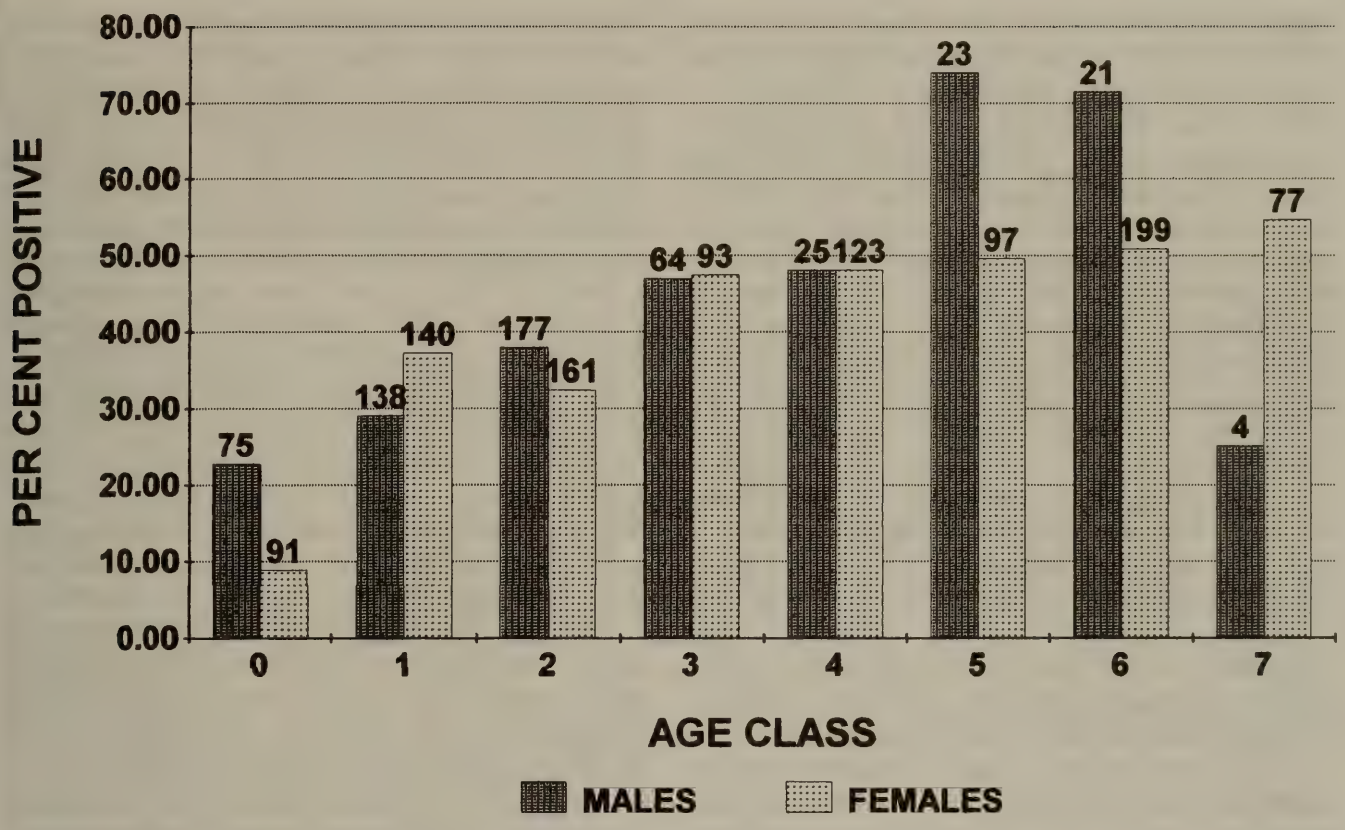

FIGURE 5. Prevalence of Tuberculosis by sex and age group in 1508 bison examined at Hay Camp, WBNP, in the years 1952-1956. (After Fuller, 1962). Numbers above bars are sample sizes.

concern that the diseases could be carried to the Mackenzie Bison Sanctuary by one or more roaming park bison.

Mackenzie Bison Sanctuary

In 1958, Dr. N. S. Novakowski located a group of about 200 bison with many of the characteristics of Wood Bison near the northern boundary of the park. In the next few years many of them were trapped and moved to corrals set up on the Salt Plains near Fort Smith. There they were tested repeatedly for tuberculosis and brucellosis. Reactors were eliminated after each test. Drs. Banfield and Novakowski (1960) examined skeletal material as well as characteristics of the living animals, and declared that the bones and the live animals belonged to the Wood Bison subspecies (*Bison bison athabascae*). Their opinion has been both questioned and supported several times since they published the results of their study. This is not the place in which to debate taxonomy, but there is no question that those animals and their descendants are the closest we will ever see to the original Wood Bison. In 1963, the captives at Ft. Smith were deemed disease-free. Eighteen of them were moved to Ft. Providence where they were released in an area north of the Mackenzie River. The area set aside for them is known as the Mackenzie Bison Sanctuary (MBS). The remainder were sent to Elk Island National Park. For more information about their fate see C. C. Gates et al.(2001).

The little group translocated to the MBS now numbers in the region of 2600 head (N.S. Novakowski, personal communication). No road runs through the MBS, but the highway between Yellowknife and Fort Providence runs along its western boundary and travellers frequently see Bison on or beside the road.

Although the Mackenzie River separates the MBS herd from WBNP, the river is not an impenetrable barrier. It can easily be crossed on the ice once it has frozen over. The probability of a diseased animal from Wood Buffalo National Park wandering as far as the MBS is low but non-zero. The herd, however, is too valuable to be exposed to the slightest danger if it can be prevented.

Conclusions

My first objective in this paper has been to show that, clearly, it can be argued that the Canadian government made a serious mistake when it gave in to public pressure some 75 years ago. Buffalo National Park was bursting at the seams with Bison. Not only was the range threatened by overpopulation, but a significantly high prevalence of tuberculosis had been demonstrated in 1923 by Hadwen and by the Waddy Report in 1924. The government of the time had at least three choices. One was to continue to slaughter large numbers every year in order to keep the population within the carrying capacity of the

range. The second was to move surplus animals to the new WBNP and take a chance that the diseases would be left behind, and that at least some of the Wood Bison would avoid contact with the introduced Plains Bison. The third choice, which was proposed by Hadwen, and backed up by Dr. Clarke, was to slaughter the entire population, allow the range to recover for a few years, and restock Buffalo National Park with healthy animals that were already available in Elk Island National Park. The third option was the only one that guaranteed that no diseases would be introduced to the Wood Bison, nor would any hybridization between Plains and Wood Bison take place.

Hewitt's suggestion to sell surplus Bison to farmers faced several difficulties. Among the most serious was that the Park lacked the facilities for holding and testing hundreds of animals every year in spite of Graham's repeated pleading for the necessary equipment. It would have been highly unethical, and probably illegal, to knowingly sell diseased animals that might end up on the farmer's dinner table.

The government put its faith in the second option, which rested on the three untested and unproven hypotheses set out in this paper. The test of those hypotheses was the transfer itself and, as we have seen, all three hypotheses were untrue. Unfortunately, the experiment was non-reversible.

My second objective in preparing this paper was to discharge the obligation I assumed regarding Maxwell Graham. I believe that the excerpts from the old files show that Graham was devoted to the Bison at Wainwright. He showed continuous concern for their health and was devastated when he learned that tuberculosis was present in the herd. He was cleared of all blame by two of his superiors in the civil service, one of whom was the Deputy Minister. He played no role in the decision to transfer young bison to the newly formed Wood Buffalo National park, and he had left the National Parks Branch some two years before the transfer began. His one transgression was the one-page letter he had published in *The Canadian Field Naturalist* that supported the three failed hypotheses. We will probably never know whether he wrote that letter on his own initiative or whether he was "asked" by one of his superiors to write it. There is no doubt that the annual calf crop in the mid 1920s at Wainwright faced an uncertain future, and I can understand why Graham sincerely believed that the transfer gave the young animals their best chance for survival.

In August of 1990 the Report of the Environmental Panel on Northern Diseased Bison was made public. The recommendation of the Panel, of which I was a member, was that all the Bison in Wood Buffalo National Park should be slaughtered. During and after the slaughter, Bison from Elk Island National Park should be bred in small enclosures in the north so that restocking with disease-free animals could take place as early as possible. The recommendation met with opposition on many fronts and, shades of 1923, the government backed down once again. The government decided to "study" the situation. Ten years on, no action has been taken.

So here we are in the new Millennium, and we are faced once again with a situation similar in many respects to that faced by the managers of Buffalo National Park in 1923–24. There is a herd of bison with a high prevalence of two infectious diseases and a declining population. There is another herd that is disease-free and flourishing. There is a low, but non-zero probability of infection of the clean herd by diseased animals wandering from their proper home. The Panel recommended total slaughter and replacement, but it did not recommend slaughter just for the sake of killing.

We must keep in mind what happened at Wainwright when the government refused to do a complete slaughter after it was shown that up to 75% of old animals were infected with tuberculosis. In 1923, the Bison population was under 7000. The total loss of life would have been less than 7000 if the whole herd had been slaughtered as Dr. Hadwen recommended. Ultimately, the protesters and a weak government were responsible for the deaths of 17 000 Wainwright Bison (Table 4), for introduction of diseases to the pristine population of Wood Bison, and for contaminating the majestic Wood Bison by hybridization with Plains Bison.

The situation in WBNP, unlike that in Wainwright, has actually improved with time. In 1990, the Bison population was more than 3300. In 1998, it was just over 2300 and declining. Some of the annual slaughters at Wainwright were as large as, or larger than, what would be needed for a final clean-up in WBNP.

There is no logical reason for further delay.

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Book Reviews

ZOOLOGY

Birds, Mammals & Reptiles of the Galápagos Islands

By Andy Swash and Rob Still. 2000. Pica Press and WildGuides, Yale University Press, New Haven and London. 168 pp., illus. U.S. $24.95.

I was delighted to find a sturdy, handy-sized guide to all the animals of the Galapagos Islands. For the traveler, size as well as quality is important. This book certainly is the right size and packs all the essential information into one volume. It covers all of the resident mammals, reptiles, and birds. It also covers the migrant and vagrant birds as well. There are introductory sections on geography, climate and habitat.

So the size and content are good, but what of the quality of the information? This is somewhat of a mixed bag. The introductory sections are logical, concise, and clear. They contain as much as I need to have in a book I plan to carry in my pocket while trudging across a tropical island. The bird section begins with an introduction to the major bird groups. The authors have used a modified taxonomic grouping that works well. This leads into the main section on the bird species.

This book relies on computer-manipulated digital images as the main form of illustration. As a result the plates look more like a "standard" field guide of the Peterson type. This is an improvement over the old sequence of small pictures. However, my arguments against photographs in field identifications still hold. For example, the Black Petrel and the Hoary Bat have a strong rosy tinge, giving a distorted impression of their true colours. The juvenile Yellow Warbler has a powder blue head. Several other birds had odd colours, including lilac-toned Lava Gull and Sora. The strangest transformation is on the female Belted Kingfisher. The breast bar is clearly visible, but the belly bar is so obscure a novice might miss it. Yet more strange is the breast bar is distinctly chestnut, instead of gray. Is this computer manipulation gone awry? Other birds on the same page as the odd ones were normally coloured. I also wonder why the authors did not change the backgrounds to give more contrast with the birds. They have brownish herons on a brownish background; grayish mockingbirds on a grayish background, and so on. If they wanted to manipulate why not follow their own fine example, the flycatcher page. This shows the birds clearly and in good proportion.

The text explains that the light morph of the Wedge-tailed Shearwater is more likely yet the plate depicts the dark morph. I would also prefer that the authors had emphasized the flight of oceanodrama petrels, a much more useful characteristic in the field.

One plate is devoted to the heads and beaks of Darwin Finches. The heads are depicted against a graph paper background and the outline of each bill is picked out in an unobtrusive gold line. Coupled with the description this is a useful tool for the inexperienced visitor.

The whale section is, for the most part, well done, with the species being depicted as you see them from a ship. While this does not show much of each species, it does present a realistic view of a typical field sighting. It also demonstrates the difficulties of field identification. I was not happy with the photograph of Cuvier's Beaked Whale. It was dark and showed little of this species' characteristics. The authors did mention the possible spotting on a Sei Whale. The Blainville's Beaked Whale is coloured red. I have not seen a Blainville's Beaked Whale, but the other beaked whales I have seen were at best described as brownish. I would be surprised to find a maple leaf red specimen.

I would like to see the authors add information on seasonal distribution. I realize most of the birds are year round residents, but there are others I question. Are the "resident" Waved A present all year or they disperse at the end of their breeding season? This information would also be valuable with scarce migrants. When can we expect to see skuas or jaegers?

Despite my comments, this is a useful field book. It is unlikely that anyone would confuse any of the species, despite the odd errors the species that could be confused are well covered. The book covers all the Galapagos animals in one handy portable volume. So I will try it in the field in late October this year. In the meantime I will be using other higher quality, but far less portable, texts for research.

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Wisconsin Fishes 2000: Status and Distribution

By John Lyons, Philip A. Cochran, and Don Fago. University of Wisconsin Sea Grant Publication No.WISCU-B-00-001. University of Wisconsin Sea Grant Institute, 1975 Willow Drive, Second Floor, Madison, Wisconsin 53706-117. e-mail: linda@seagrant.wisc.edu. 87 pp. U.S. $10.

One wonders if the Electronic Age will make peer book reviews less important, or more important. An eight-page description of this book is available at http://www.seagrant.wisc.edu/greatlakesfish/Lyons.htmf. This is my first experience evaluating a publication with most of the routine items, or samples, readily at hand.

The header on each of the eight pages of the Internet description uses the statement "Wisconsin Fishes 2000/Fish of the Great Lakes by Wisconsin Sea Grant." This Great Lakes emphasis is not mentioned in the book. Great emphasis is placed, by the authors, on the literature since Becker's (1983) Fishes of Wisconsin, and the fact that this publication updates the information on "occurrence, taxonomic status, and abundance of fishes *in Wisconsin*". Fishes in the waters of the Wisconsin portions, and at times the adjacent Michigan portions, of lakes Michigan and Superior are, however, included.

Individuals interested in the status and distribution of fishes in Wisconsin, and comparisons with those in the geographic areas around Wisconsin in the USA and Canada, owe a debt of thanks for the extensive and constantly updated information since Becker's 1983 book, in the 22 related publications by these authors and coauthors, and those of several other authors. Much of the information in this book was derived from the "Master Fish File", a database including 22 000 Wisconsin fish collections from 1900 to 1999. The database can be accessed through the web site of the Wisconsin Department of Natural Resources (www.dnr.state.wi.us).

This book includes sections entitled Summary, Introduction, Materials and Methods, Overview of Changes in the Wisconsin Fish Fauna, Species Accounts, References, Index to Common Name, Index to Species by Scientific Name, and eight colour plates.

The overview of changes includes a table with sections entitled Native Species (147), Established Non-Native Species (14), and Transient Non-Native Species (19). In total those sections include 180 species. One of the problems of lists is the necessary, sometimes arbitrary, decisions required when authors decide where to put various species. Readers may not have made the same decisions.

Five species not included in earlier publications are included here. Those are Kokanee, *Oncorhynchus nerka*, Threespine Stickleback, *Gasterosteus aculeatus*, White Perch, *Morone americana*, and Round Goby *Neogobius melanostomus*.

There are species accounts for 182 forms, ranging in length from a few lines to several pages. The emphasis, in length, is on the more recently discovered species, native and introduced. Many of those were not given full treatment in Becker's 1983 book. Only eight of the species accounts include a "spot" map of those locations at which the species has been collected, or observed by one of the authors. The longer species accounts usually include Common Name; Scientific Name; Description, including means of separation from look-alike species; Systematic Notes; Distribution, Status, and Habitat; Biology; and Importance and Management. The distribution statements, and absence of a map, in the shorter Species Accounts leaves the reader unable to determine if the species occurs in lakes Michigan and/or Superior. Some species accounts deal with extirpated species, and species rediscovered as present.

The book includes eight colour plates tipped into the front before the title page, somewhat like a Frontispiece. The plates are of seven recently discovered forms. There is one unfortunate problem. The caption of one of the two plates for the Round Goby, *Neogobius melanostomus*, incorrectly identifies the "fused pectoral fins", whereas the photo clearly indicates that it is the pelvic fins which are fused forming the diagnostic "sucking disc" of gobies.

There are a number of interesting points to be derived from the lists and accounts. The abundance of natural reproduction of Lake Trout, *Salvelinus namaycush* in the Wisconsin portion of Lake Superior has led to stocking being discontinued there. The same is apparently true for Chinook and Coho salmon, *Oncorhynchus tshawytscha* and *O. kisutch*. In contrast, for Pink Salmon, *O. gorbuscha*, there has been no natural spawning in Lake Superior streams since the late 1970s and the species is now rarely seen in Wisconsin waters of lakes Superior and Michigan. There have apparently been no records of the European Flatfish, *Platichthys flesus* from Wisconsin waters of lakes Michigan or Superior. This is in contrast to the fact that Ontario records for Lake Superior are almost as numerous as those for Lake Erie. The Warmouth, *Lepomis gulosus* has now been reported from (the southern part of ?) the Lake Superior Basin. This species is easily confused with the Rockbass, *Ambloplites rupestris*, and even though Lake Superior may be more of a barrier (cold) to immigration, with the experience on Lake Erie its arrival in Lake Superior should be watched for.

There is, presently, a great emphasis on maintenance of biodiversity, rehabilitation of native species, and the controversy around "Is more better?". This commitment cannot hope to succeed

without constant surveys, species status reports, checklists, and publications like this one and the others which have appeared in Wisconsin. Too often, surveys and updates, such as this one, are deemed less important than "more sophisticated" research. I hope the people in Wisconsin will continue to be supported philosophically and financially to set an example for other Political areas. I found the book interesting and useful. I'm certain that fish biologists in Wisconsin are finding it useful, as will the next person charged with updating a checklist of the fishes of the Great Lakes Basin.

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Marine Mammals of the Pacific Northwest: A Concise and Comprehensive Waterproof Guide

By P. A. Folkens. 2001. Harbour Publishing, Madeira Park, British Columbia. 8 pp., illus. $9.95.

The increasing development of the whale-watching industry has resulted in the demand and creation of books and identification guides for sea mammals, seabirds, and other parts of the marine ecosystem. In this regard, and looking back on a history of whale watching for over 90 years, the coast of British Columbia has received most of the publication activity in Canada.

Despite its catchy title, this guide by Pieter Arend Folkens is more a leaflet than a guide. It consists of three text pages and five pages of drawings and photos full of information for the whale watcher in the field. Although the leaflet is printed on "waterproof, UV resistant synthetic film made from a 100% recyclable, environmentally inert material containing no forest products (similar to milk jugs)", the user might actually have difficulties using it on an offshore whale watching trip during periods of strong wind or high waves; the light leaflet could easily fly away and the small print is hard to read when on a rolling boat. However, the compressed text gives a nice summary and overview on 31 sea mammal species in the area; it even mentions Steller's Sea Cow which was hunted to extinction by 1768. In addition, major whale watching locations in British Columbia and Alaska are named; but none are specifically reported for Oregon and Washington (as the title would imply).

Most of the eight pages of the field guide are devoted to drawings and to fine pictures from the author and several others. The reader might find the distinction between *Mysticetes* (Baleen Whales), *Odontocetes* (Toothed Whales), and Small Cetaceans a little unclear from the arrangements of the drawings. Very helpful and informative is the page about "Common visible behaviors and terms" allowing to link sea mammal sightings to a classified set of behaviour types. Helpful also is that images of fluke displays are presented for species that are known to show such behaviour. Even the body sizes of newborn sea mammals are given. All measurements are made in SI units, and the conversion factor for feet is provided.

Of interest to the general audience might be the section "Marine Mammal Watching Guideline," also presented on the web [http://www.fakr.noaa.gov/protectedresources/mmviewingguide.html] (Note that the old URL www.nmfs.gov/prot_res.html and given in the guide was updated). In addition, contact addresses and a web address (revised to http://www.fakr.noaa.gov/protectedresources/strandings.htm) are given for sightings of stranded sea mammals (Canada: Department of Fisheries and Oceans 800 465-4336; or the Whale Reporting & Stranding Line 800 665-5939).

As in many other field guides, the text suggests some field marks and details for species identification and separation that normal whale watchers might not be able to apply, or which are not really realistic. For instance, Sei Whales are supposed to be differentiated from Fin Whales by a fin angle of over 45 degrees; male Beaked Whales (Genus *Mesoplodon*) ideally can be identified by the location of teeth and jaw line (which is, for most of the time, covered by the ocean); phocids (true seals) differ from otariids (Sea Lions and Fur Seals) by their hair and small nails on their foreflippers. Overall, features like these might be very hard to recognize for the untrained as well as for the trained observer, particularly when observations are made of moving animals some distance from a shaky boat, with binoculars. Rather than focusing on classical small-scale features, an outline of the use of proportions and shapes could be more useful for distinguishing species. Counterproductive for a field guide might be the point that Beaked Whales, the species group that lacks most knowledge on distribution and where whale watchers could indeed contribute greatly to science, are described as the "most difficult whales to identify correct." No further help or details are given for the interested whale watcher.

For my taste, the "Habitat and Symbol Keys" that are supposed "to narrow possibilities in a particular era" and link sea mammals with "habitat" are not really helpful. Many whales migrate across habitats and the regular observer has no real way to tell "temperate" habitats apart from "cool temperate" ones. The meaning of the orange W habitat class presented for the False Killer Whale will likely remain a mystery to the reader because its meaning is unexplained in the guide. For pinnipeds, their "calls" and the mention of rookeries could have been helpful.

Overall, it appears that this "guide" is an excerpt of a better and larger guide book from the same author. It is useable in the field, but does not replace the real and classical guide books.

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Manitoba Birds

By Andy Bezener and Ken de Smet. 2000. Lone Pine Publishing, Edmonton, Alberta. 176 pp., illus. $17.95.

I often wonder in which market book writers think they will sell their product. My first reaction to this compact little book, covering only 145 species (out of the official list of 406) was that it was too simple for most birdwatchers. And it probably is. Then I realized it was ideal for scout leaders. It gives a short, easy-to-read account of a bird's character, and a sentence or two on identification, size, status, habitat, nesting, feeding, voice, similar species, and the best sites in the province (to see the bird). An illustration and a range map accompany this information. This is just about the right level of detail for a scout leader teaching his troop about birds. It is also good for schoolteachers, new birders, and children. While it is intended for use in Manitoba, it would also be a useful guide throughout the prairies.

The introduction has a map of the natural regions showing the best 50 birding sites. A dozen sites have a short write-up that includes the most prominent bird species. I liked this addition to the text. I thought beginners and visitors would be able to use it as a starting point when organizing trips. Each account has a small illustration. While most of these are reduced (and reversed) versions from the main text, five species are different and not covered in the core section of the book. I counted 145 in the main text, so there is a total 150 species illustrated. These additional species, which this guide explains you can find most easily in the places mentioned, would be better included in the central body of the book (in replacement for some of the rarer or more difficult to see birds).

The authors claim the birds selected are the most common and easily found within the province. I question some of the choices. They have chosen, for example, Burrowing Owl, a rare nester in the south west corner of the province and Screech Owl which nests along a narrow strip close to the U.S border (the range map for this owl seems a trifle optimistic). Yet they left out Hawk Owl, a widespread bird which nests over the northern three-quarters of the province. Birds seen easily in the north (Churchill) but not in the south, such as Bonaparte's Gull, jaegers, ptarmigan, and plovers, are also not included. Generally, though, I found the choices to be reasonable for the populated south of the province. I would be surprised if House Sparrow is not found at northern towns like Lynn Lake and Thompson (the range map does not suggest this.)

The illustrations by Gary Ross, Ted Nordhagen, and Ewa Pluciennik are, for the most part, very good. They generally show a typical adult in summer plumage. For some, but not all, species the differences between male and female are shown. Winter visitors are depicted in the appropriate non-breeding plumage. Many birds are shown in flight too. I was very impressed with the shape, attitude, and technical detail of each species. I did find a few that I thought could be improved (Warbling Vireo is too pale and Olive-sided Flycatcher is not heavily built or boldly coloured enough), but overall the quality is first rate.

This is a compact (14 × 21 × 1 cm) little book that will easily slip into a pocket or pack. The plasticized cover and high quality production suggests it should last well in the field. A quick colour-coded guide to the bird families on the back cover will also help out novices to find the appropriate text.

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Heron Conservation

Edited by James A. Kushlan and Heinz Hafner. 2000. Academic Press, London and San Diego. xvi + 480 pp. illus.

This publication is a cooperative one, with 19 major contributors and a multitude of cooperators from the Herons Specialist Group, an international network of experts in the field of herons and wetland protection. Their objective was "to synthesize and summarize the state of knowledge of the conservation needs of herons throughout the world."

The book opens with eight chapters on the status of herons in major geographic regions — either continents or sub-continents. The herons of each area are reviewed species by species, with estimates of their numbers, or at least their status and conservation needs. Of necessity there is much variation in the coverage, with considerable detail available on European species and lamentably little for many Asian and South American ones. Next come seven chapters on various aspects of heron conservation, covering such topics as habitat conservation, aquaculture, and environmental contaminants, then a chapter on research and information needs, and finally a synthesis of the conservation needs for the most vulnerable species. There is an extensive bibliography and a well-organized index.

Any book devoted to the conservation needs of any group of species on a global scale these days makes for depressing reading, and this work is no exception. Information is lacking on even the most basic aspects of life history and distribution of many more elusive herons, and the sad chronicle of habitat loss, exploitation, and persecution is common to all too many species cross the world.

Still, this is hardly news to anyone interested in birds, and I found myself wondering about the audience for a work of this kind. Action on any individual species or group of species will necessarily be quite specific to the local conditions and the needs of the birds. Much of the information given here, however, is very general, perhaps inevitably so given the enormous scope of the book. One would think this information would already be well known to those working in the field, yet at the same time the very specific scope of the book limits its appeal to a broader audience.

In an attempt to assess its relevance to those species that I am most familiar with, I placed particular emphasis on the North American chapter. I was left with a distinct sense of disquiet. Its general tone of optimism runs contrary to my own experience on an admittedly very limited, local scale. It's true, of course, that our problems are minor when compared to the enormous challenges elsewhere, but at the same time the problems are real. I'm not sure that cheerfully quoting the Canadian government's policy of "no net loss" of wetlands is particularly helpful when — as the authors themselves concede — it only applies to the 29% of wetlands that are federally owned, most of which are north of significant heron range. Many of the wetlands I know are privately or provincially owned, and dying the death of a thousand tiny cuts, while supposedly safeguarded by underfunded agencies reporting to unsympathetic governments. I question the statement that "It is likely that, overall, the loss of wetland has been halted in Canada . . ."

I found myself equally at odds when considering some individual species, again finding more seeming optimism than I can share. On the Least Bittern, for example, the authors do stress the lack of good data and the fact that in 1986 birders were already expressing concerns about the species. But then the 1965–1979 Breeding Bird Surveys, of all things, are cited as indicating "some evidence" of increases. The reference is correct as far as it goes, but when one considers that in 1997, for example, a grand total of 18 Least Bitterns were recorded on only seven of 1832 BBS routes continent-wide, one wonders how useful its' information is in the present context.

But perhaps the authors are indeed right on a continental scale, and then the bothersome part is their conclusions could easily seem to justify complacency generally. They would doubtless respond that all the caveats about lack of data and "alteration of wetland functions" [replacement of marshes with boat docks, perhaps?] are there. Indeed they are, but they only "temper" the rosy picture they have already drawn, poor data or not.

However, none of the other continental authors seem quite so comfortable with the conditions their herons face, and the book as a whole seems to achieve its objective of pinpointing those areas that need action to conserve heron species world-wide, and the kinds of action needed. The chapters on research and information needs, and the final synthesis should be particularly useful in this regard. If one issue emerges as of paramount importance everywhere as a critical first step, it is the pressing need for more data, and particularly more precise data, to allow species' status to be understood.

This book is an important one for anyone interested in heron conservation. While North American readers may share my irritation at the authors' approach, careful reading will still yield a reasonable summary of the issues we face in conserving our herons. However, the book's appeal to a broader audience is necessarily limited.

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The Field Guide to the Birds of Australia

By G. Pizzey and F. Knight. 1999. Revised Edition. Angus & Robertson, Sydney, Australia. 576 pp., illus. AUD $39.95.

The success or failure of any field guide depends on its ability to convey information necessary for correct species identification. The latest edition of *The Field Guide to the Birds of Australia* by veteran author Graham Pizzey and illustrator Frank Knight accomplishes this objective, and does so in an appealing format.

The introduction to this edition provides a primer for those new to birding, or for those wishing to "brush up" on their terminology. A generous mix of illustrations, text, and examples are used to familiarize the reader with descriptions of anatomy, field marks, and behaviours. Although reading this section is not essential to understand the field guide, it will assist the novice birder in gaining the most from a birding excursion.

Following the introduction, there are species accounts for 778 native and introduced species with 700 distribution maps. Typically, there are 3–4 species accounts per double page with text and color illustrations opposite each other. Descriptions for each species include information on (1) other names, (2) similar species, (3) voice, (4) habitat, (5) breeding season, (6) nests, (7) eggs, and (8) range and status. The range information is particularly useful since it refers to place names, easily found on maps conveniently included inside both covers. The colour illustrations are well done and depict male, female, and juvenile plumage; races and moult patterns also are provided to facilitate identification.

The species accounts are followed by an introduction to the bird families of Australia. General characteristics of each family (i.e., behaviour, food, and range) are presented in the same order in which they appear in the species accounts. The world range of each family is provided, as are the number of species within each family and the number of those that occur in Australia (both native and introduced).

There are few flaws in the guide. The species accounts and illustrations are helpful and well organized. It would have been useful, however, to include migratory information on the distribution maps, perhaps with seasonal ranges depicted with separate colours. Distribution maps for some introduced or rare species are not provided and would have been a nice feature.

As a new resident of Australia, and unfamiliar with the birds I was to encounter, I found this field guide to be of great assistance. It is small and hardy enough to toss into a daypack, but also would make a useful reference for anyone interested in Australian birds.

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Katydids and Bush-Crickets: Reproductive Behavior and Evolution of the Tettigoniidae

Darryl T. Gwynne. 2001. A volume in the Cornell series in arthropod biology (John Alcock, editor). Cornell University Press, Ithaca. xii + 317 pp., illus. U.S. $42.50.

Darwin (1871) introduced the theory of sexual selection as an attempt to explain the evolution of such traits as bright colours, huge feather plumes, antlers, and other male adornments, features that by their highly conspicuous nature, seemed highly unlikely to confer survival advantages on their bearer. Sexual selection (differential reproductive success resulting from competition for mates) as a topic of investigation lay essentially dormant for about a century. However, since the mid-1970s, interest in sexual selection has blossomed (yes, it occurs in plants, too!), following the recognition that it is a major evolutionary agent.

Sexual selection is the underlying theme of Gwynne's book, which in this respect is similar to those of Eberhard (1985, 1996), Gould and Gould (1989), and Andersson (1994). However, it has the advantage over these contributions in that it deals with the phenomenon in a specific taxon, the family Tettigoniidae, which has allowed the author to present his ideas on a solid platform of basic biology. Indeed, the author's successful aim is not only to interest students of sexual selection, but to show naturalists what a fascinating group of insects the tettigoniids are.

For field naturalists, the early chapters, which deal with evolution, diversity (more than 6000 species arranged in 17 subfamilies), life histories, food preferences, natural enemies, defence mechanisms, and sound communication, will probably be of most interest. Behaviorists, especially those who focus on reproductive behaviour, will find much food for thought in the second half of the book. However, animal biologists in general will find the entire volume contains much to hold their attention.

The book is profusely illustrated with line drawings, black-and-white photographs (some of which,

unfortunately, lack contrast), and four pages of color plates. The text is generally well written and Gwynne's approach (present the hypothesis, then examine the evidence) is highly recommended as a "model" for developing researchers. Occasionally, the author "overindulges" by giving too many examples to illustrate a point, and the editor might have used a sharper pencil to remove redundancy and repetition and a sharper eye to ensure that the indexing is accurate. I stress, however, that these are minor "complaints" and my overall opinion is that Gwynne deserves full credit for his synthesis of the biology of this major, yet not well known, insect group.

Literature Cited

Andersson, M. 1994. Sexual Selection. Princeton University Press, Princeton, New Jersey.

Darwin, C. 1871. The descent of man and selection in relation to sex. John Murray, London.

Eberhard, W. G. 1985. Sexual selection and animal genitalia. Harvard University Press, Cambridge, Massachusetts.

Eberhard, W. G. 1996. Female control: Sexual selection by cryptic female choice. Princeton University Press, Princeton, New Jersey.

Gould, J., and **C. G. Gould.** 1989. Sexual selection. Scientific American Library, New York.

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A Manual for Wildlife Radio Tagging

Robert E. Kenward. 2001. Academic Press, San Diego, California. 311 pp., illus. U.S. $65.00.

This book is a significant updating of "*Wildlife radio tagging: equipment, field techniques and data analysis*" (Kenward 1987). The book incorporates much new information developed since the late 1980s and includes all of the original topics from the earlier volume but is 70% larger.

Kenward starts this book with the logical least common denominator, that is, deciding whether radio tagging is an appropriate option for collecting data from a subject animal and planning projects. Once the decision to radio tag is made, you proceed through the chapters of the book to determine the appropriate equipment, how to obtain equipment, how to make and attach radio tags, proper radio tracking technique, and data analysis.

It is unfortunate that this volume contains many errors, particularly in the literature cited. Some of the errors can make it difficult for less knowledgeable readers to locate and obtain references.

This book is aimed at the beginning researcher contemplating use of radio tagging as well as the more experienced. Even with the errors as noted above, because of Kenward's depth of knowledge and extensive experience with tracking, this book is of definite value to any and all researchers that are considering or applying telemetry to their research. It is highly recommendable for its thoroughness, timeliness, and user friendly organization. Those already owning the earlier volume should still consider purchasing this new version.

Literature Cited

Kenward, R. E. 1987. Wildlife radio tagging: equipment, field techniques and data analysis. Academic Press, San Diego, California.

ROGER D. APPLEGATE

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Bird Census Techniques

By Colin J. Bibby, Neil J. Burgess, David A. Hill, and Simon H. Mustoe. 2000. 2nd edition. Academic, London. 301 pp., illus. U.S. $55.00.

The global concerns for the plight of long distance migratory birds and efforts to develop comprehensive conservation plans in North America encompassing all avian species make the need for statistically valid bird census techniques evident. This book, updating and expanding the first edition, fills that need.

The authors have incorporated the vast literature of bird censusing to make this volume a comprehensive reference. Each major bird counting technique is given a thorough treatment in cook-book fashion that makes it possible for anyone to lay out and conduct the count. The book also provides a general background on design of bird censuses and statistical issues. There is information on use of computer software provided in the chapter on line transects.

The book has chapters on applying census methods to specific species. These chapters deal with species that are largely European. However, in most cases, the techniques can be applied to closely related North American species. For example: Willow Ptarmigan (*Lagopus lagopus*) and Red Grouse (*L. l. scoticus*).

Bibby et al. is relatively free of errors. Those noted were minor and do not detract from the readability or utility of the book. I would like to have seen some thoughtful discussion of issues relating to the use of index methods as opposed to methods that provide an estimate. However, overall this book has met the authors' objectives of providing a comprehensive reference on bird censusing. I recommend this book to all who are conducting or will be conducting such field studies. For those owning the first edition, I recommend purchasing this second edition.

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Flying Foxes: Fruit and Blossom Bats of Australia

By L. Hall and G. Richards. 2000. Krieger Publishing Company, Malabar, Florida. viii + 133 pp., illus. Cloth U.S. $29.50; paper U.S. $21.50.

I have had a great interest in flying foxes since I first saw them roosting in a tree in Indonesia about 20 years ago. Their size and open nesting sites in an urban area made them far more spectacular than the Canadian cave species that I had studied as a graduate student or even the variety of species I had collected in the Amazon region of South America. In recent years (including the time I am writing this), my house in Ibadan, Nigeria, allows me to go out every evening and watch spectacular, huge clouds of flying foxes migrating overhead from their daytime camp in an urban, botanical garden, where they are safe from hungry hunters, to their evening fruit-tree feeding grounds.

The flying foxes are fruit and nectar eating bats of the suborder Megachiroptera, which are found in the old world tropics and are only distantly related to the suborder Microchiroptera which I studied as a student. This book did confuse me a bit, at first, since the authors primarily discuss only Australian species and the most common of these in the genera *Pteropus*, which does not occur in continental Africa. The authors state in the introduction "There is a number of other fruit-eating Megachiroptera which are not in the genus *Pteropus* but which are also called 'flying foxes'. " Then throughout the rest of the book they talk of flying foxes as if they were only Australian *Pteropus*. This caused me considerable confusion since I have been involved in some flying fox research in Nigeria, and I know this is not Australia. Back to my early lessons about how Latin, scientific names are so much more precise than common names.

This book is very comprehensive, well researched, and well written. It provides excellent information to those who are interested in flying foxes, even if not just in Australia. It covers such areas as history and archaeology, identification, and distribution of the Australian species, anatomy and physiology, disease, behaviour, feeding ecology, migration, conservation, rehabilitation, and even hand rearing, in great detail. Appendices include native plant foods, extensive references, a glossary, and index. There is some confusion where references in the text to an individual or institution doing research cannot be traced to the specific published references at the back of the book.

Some very interesting facts are presented in this book. Did you know that bats are the second most common mammal group to rodents. Then there is the blossom bat, described as a "mouse-sized flying fox" — a bit of a contradiction. Flying foxes, unlike other bats, rely largely on sight. They will not fly in total darkness and do not hear much better than a human being. Their vision is similar to that of a cat. During the day, flying foxes roost together in large "camps" which can number over 250 000. These camps can be very noisy and result in damages to the local trees. At night, they will migrate long distances to feed, again causing damages due to their numbers. This has resulted in cropping by orchard owners, which has decimated the population in Australia. They are now protected and conserved for their beneficial behaviours such as pollination and dispersal of fruit seeds.

Flying foxes have learned the behaviour of roosting in urban forests or parks as a protection against shooting. In my area of Nigeria, the largest local camps are the botanical garden close to our house, and two local university campuses. Flying foxes are considered a culinary delicacy in Nigeria as well as elsewhere in their range. One of my co-workers here says they make delicious soup. But he was surprised that they do not taste like a bird. Usually if I eat bush meat, I do not ask what it is.

With a lifespan (in captivity) of up to 50 years, flying foxes only produce one young per year. This has resulted in serious population drops due to habitat loss and hunting pressure. Several southeast Asian islands have seen populations become extinct

and the entire population of some species in Australia is now smaller than the 300 000 reported in one camp less than fifty years ago. Another species which I hope will not disappear before we have really had the chance to get to know it. This book is a very worthwhile and authoritative source of information on the intriguing world of flying foxes.

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BOTANY

Guide to Standard Floras of the World: An Annotated Geographically Arranged Systematic Bibliography of the Principal Floras, Enumerations, Checklists, and Chorological Atlases of Different Areas. Second Edition.

By David G. Fordin. 2001. Cambridge University Press, The Edinburgh Building, Cambridge CB2 2RU UK; 40 West 20th Street, New York, NY 10011-4211, U.S.A. xxiv + 1100 pages U.S. $240.00 + $6.00 postage.

This volume, which includes information on all the floras of the world known to the author up to the end of the twentieth century, is a tremendous step ahead of the first edition which was published in 1984 and numbered 619 pages. The first pages of this volume include prologues and acknowledgements of the first and second editions; Part I which numbers 84 pages and includes an analytical-synthetic systematic bibliography of "standard" floras: scope, sources and structure, the evolution of floras, floras at the end of the twentieth century: philosophy, progress, and prospects and references. Part II includes systematic bibliography, conspectus of divisions and superregions, world floras, isolated oceanic islands and polar regions, and divisions: North America (north of Mexico), Middle America, South America, Australia and islands of the southwest Indian Ocean (Malagassia), Africa, Europe, northern, central and southwestern (extra-monsoonal) Asia, southern, eastern and southeastern (monsoonal) Asia, Greater Malasia, and Oceania. This is followed by Appendix A: major general bibliographies, indices, and library catalogues covering world floristic literature, and Appendix B: Abbreviations of serials cited, addenda in proof, geographical index, and author index.

The main part of this volume then proceeds through the areas listed in Part II above with descriptions of the regions, locations, number of species, early botanical history up to the end of the twentieth century, and the major floras which have been published through the years. There is a wealth of information here both for those living in any region or anyone interested in the botany of another part of the world.

It is inevitable in a work such as this that occasionally some useful publications will be passed by. Some from northern North America that might have been included are the following:

Benson, L. 1982. The Cacti of the United States and Canada. Stanford University Press.

Biek, D. 1999. Flora of Mount Rainier National Park. Oregon State University Press.

Cody, W. J. 1988. Plants of Riding Mountain National Park, Manitoba. Agriculture Canada.

Douglas, G. W., C. B. Straley, and **D. V. Meidinger.** 1998. Rare Native Vascular Plants of British Columbia. Crown Publications.

Hallworth, B., and **C. C. Chinnappa.** 1997. Plants of Kananaskis Country in the Rocky Mountains of Alberta. University of Calgary Press.

Holmgren, A. H. 1998. "Illustrated Companion to Gleason and Cronquists' Manual: Illustrations of the Vascular Plants of Northeastern United States and Adjacent Canada". The New York Botanical Garden.

McGregor, R. L., and **T. M. Barkley.** 1977. Atlas of the Flora of the Great Plains. The Iowa State University Press.

Packer, J., and **C. E. Bradley.** 1984. Checklist of the rare plants in Alberta. Provincial Museum of Alberta National History Occasional Paper Number 5.

Petrik-Ott, A. J. 1979. The Pteridophytes of Kansas, Nebraska, South Dakota and North Dakota. Nova Hedwigia, Beiheft 61.

Argus, George [*Series Editor*] 1977–1995. Rare Native Vascular Plants of Canadian Provinces and Territories. Syllogeus National Museum of Natural Sciences, Ottawa.

Tryon, A. F., and **R. C. Moran.** 1997. *The Ferns and Allied Plants of New England.* Centre for Biological Conservation, Massachusetts Audubon Society.

Botanical studies will continue around the world and already one for the year 2000 has been published in Canada: H. R. Hinds, *Flora of New Brunswick*, Second Edition, which was a great step ahead from the First Edition. It will be most important to keep *The Guide to Standard Floras of the World* up to date through new editions or supplements.

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EVIRONMENT

Their Fathers' Work: Casting Nets with the World's Fishermen

By W. McCloskey. 2000. International Marine/McGraw-Hill, New York. 370 pp. U.S. $20.95

This book provides the reader with a superb and highly praised overview of global fisheries, focusing on Alaskan waters. In addition, it also covers first-hand experiences for offshore and coastal fisheries with vessels from Japan, Chile, Indonesia, Newfoundland (Grand Banks), Maine (Georges Bank), Iceland, and Norway. The book is very pleasant to read as it combines fiction with fact. It is a heroic and romantic description of a likely soon-to-be-gone life of hard work. Nevertheless, reading how other people work very hard and under life-threatening conditions might present some sort of decadence; but so be it.

In case the reader is not familiar with how to cheat in this business of international fisheries and quotas (led by Spain, Taiwan, Japan, and many East European nations) this book will be enlightening. It outlines in detail how fishing quotas are easily doubled, if not ignored, by many vessel captains and fishermen worldwide. The explicit use of Dynamite Fishing, Liner Nets (an additional net with an illegally smaller mesh-size put inside the regular net), the "Pareja" Method (one huge net pulled by two boats), and many other tricks are shown and suggested: e.g., the same vessel being registered with two different names (thus, multiplying the quota by two), stowing an additional catch somewhere under deck, trading the catch offshore (therefore enabled to start again with a "new" quota), and mis-reporting catches. When fisheries officers appear for control and gear inspection, nets simply get cut off (which makes it even worse for fish, seabirds, and sea mammals that drown in the "ghost nets" later). Overall, I find that the author, an American, might have a tendency to put too much blame on the Spaniards and Russians. Instead, a mention and description of the role that the Vladivostok-based Russian fisheries play, acting worldwide, could have made the book even better.

The thorough understatement of environmental damage done by coastal and offshore fishery must be of concern to any informed naturalist. The author neglects to address the destructive fishery method from draggers ("seafloor dredging"), which is estimated to damage an area larger than that lost through deforestation in the tropics. There is no mention of fisheries gear polluting beaches worldwide, or "ghost nets" which float around the world's oceans for years (eventually, they will sink, but only the fish know whether they will ever rot). Sensitive by-catch topics such as the endangered Short-tailed Albatross (*Phoebastria albatrus*) caught by freezer-longliners fishing off Alaska are not mentioned, and certainly there is no reporting of the numerous sea turtles, sharks, dolphins, porpoises, seabirds, moon fishes, and many other species suffering and dying for the sake of high quality fish. In times of environmentalism, that might be seen as a short-coming of this book. Although the occurrence of a "black catch" is somewhat mentioned, one reads that shrimp fisheries have apparently almost no by-catch. The reader has to hold his/her breath when McCloskey mentions "overpopulations" of Sockeye and seals; 50 000 seals are described as an "overpopulation" rather than victims in a potential by-catch problem. No wonder, the author identifies clearly from the "fishermen's side", blames Greenpeace, and does not place fisheries in the overall context of the environment. Instead, he largely focuses on economical and descriptive aspects of fisheries. In this regard, the author's presentation of Chile's fishery development lacks sensitivity to the well-proven and negative effects of over-commercialization. On the other side, his wonderful and detailed presentation of the effects from the Exxon Valdez Oilspill for Alaska and its island communities compensate for the previous short-comings. A remarkable link is shown why the prizes of the Japanese salmon market are driven by cycles of the Japanese salmon runs and thus dictate the Alaskan salmon fisheries. McCloskey gets closer to the heart of the fisheries problem when outlining that improved efficiency and introduction of very light, and therefore allowing for longer, plastic nets has contributed to the current overfishing crisis.

In the numerous and fascinating chapters the author also emphasizes and describes that there exists such a thing as severe overfishing: Snow Crab in Alaska; Cod, Flounder and Squid in Newfoundland; and Halibut off West America. He blames governmental mis-management and elaborates nicely throughout the text that there is also conflict of interest among fishermen on these topics; e.g., unions, and small scale fisheries vs. industrialized trawlers. In the context of governmental mismanagement, New Zealand's Orange Roughy, a prime example of overfishing and disastrous fisheries management, could have been mentioned, too. The book would have been even better if topics such as a Native Fishery Rights, North Sea Fisheries, and Krill Fisheries in the Antarctic had been included. The map of the Grand Banks lacks the French Fisheries zone around St. Pierre and Miquelon; but the reader will appreciate that this book has a very detailed index, which allows that it can serve as a valid source of references.

The book ends with a well-written and conclusive section on global fisheries and policy. The author quotes from one of his many interviews with

experts: "*Gathering fishery statistics is an art in probability*". That statement makes it clear that, currently, there can be no sustainable world fisheries. Due to the many topics covered, I thoroughly enjoyed reading this book and got literally "hooked".

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AAAS Atlas of Population and Environment

By P. Harrison and F. Pearce. 2001. University of California Press, Berkeley. xi + 204 pp., illus. Cloth U.S. $65; paper U.S. $29.95.

Population is the main cause of environmental problems. This book provides an excellent, well-documented, and authoritative demonstration of this principle, using easy to read text and great atlas displays. It needs to be read by every person who is concerned over our world environmental degradation and the population impacts of the very near future. It comes home to me personally, spending much time in Nigeria, one of the highest and most densely populated countries in Africa. In spite of the HIV-AIDS epidemic, it still has one of the highest population growth rates in the world (2.81% per year). Here one comes face to face with poverty, lack of clean water supplies, major losses of forest and ecological habitat, desertification, and the desperation of many people struggling to survive from day to day. I see things that I never would have believed before I first came here 10 years ago. What will it be like in 2050 AD when the population is expected to grow by more than 50% to about 200 million people (in an area the size of Ontario, with large areas of arid savanna). This book gives some predictive outlook for such areas of the world, where the major population growth will be in the future. I do not think this is an issue that we can afford to ignore. Perhaps, as a bit of a field-naturalist heretic, I suggest that it is more of an environmental priority than the birds in our back yard. I recommend this book as a critical reference, resource for anyone concerned about the environment and the future of our world.

The book is organized into three major sections. Part 1: Overview (40 pages) is primarily introductory text, covering issues such as environmental policies and philosophies, the scale of our existence, and the theory of population-environment links. How many people can the world sustain? This area is not well understood and the answer is not given, but theories such as those of Malthus and Erhlich are analyzed in an impartial scientific manner. Much data is presented, but the reader is often left to make their own conclusions. In the last century population expansion has occurred at an alarming, unprecedented rate (from three million — 2000 years ago, to 1 billion 200 years ago, to over 6 billion now, and predictions to over 9 billion by 2050). In the last century, we have lost/of the world's topsoil, 1/5 of our agricultural land base, major parts of our forest, and other habitat. We have experienced a species extinction rate 100 times that of any time in our previous history. Our problems are summarized in a rather sickening and scary manner, but easily understood by those of us who live much of our lives in the third world.

The second part of the book is 164 pages of an atlas of resources and resource uses or losses, along with some accompanying discussion and references. Areas covered include population effects on natural resources, land use, atmosphere, wastes and chemicals, ecosystems, and biodiversity. The atlas maps allow easy reference and the text provides excellent detail.

The third part of the book provides a few case histories of population-environment interaction, for different biogeographic regions of the world. All but one are taken from World Wildlife Fund information. The one exception, and location closest to Canada, is a Nature Conservancy discussion of the Sonoran Desert (a favourite retreat for me).

I guess Canada can be happy to be on the good side of most of these environmental issues and to be proud not to have a case history illustrated here. However, I do strongly believe that we cannot hide from these potential future population-caused environmental catastrophes. We are all in one world and the information in this book is an excellent start to planning to save it.

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Making Better Environmental Decisions

By Mary O'Brien. 2000. The MIT Press, Cambridge, Massachusetts. 286 pp., illus. U.S. $22.95.

This book starts with a story, a parable of sorts. A woman is standing by an icy mountain river, intending to cross to the other side. A team of risk assessors accompanies her, reviewing her situation. They present arguments and calculations, concluding that the risk she faces is low from their various perspectives — toxicology, cardiology, hydrology, policy — and that she should wade across the river. Yet, to their extreme frustration, she refuses to wade. Why? She points upstream and tells them, "Because there is a bridge."

The risk assessors evaluated the risk of only one option: wading across the river. The woman reviewed her alternatives, which included crossing on the bridge upstream. *Making Better Environmental Decisions* is about doing what the woman in the parable did: making decisions based on all possible alternatives instead of considering only the risk associated with a narrow range of options.

The concept of alternatives assessment is based on certain common-sense principles. These include, among others, that it is unacceptable to harm human or non-human life when reasonable alternatives exist. That nobody should be able to define for anyone else how much damage is "acceptable". That those affected by decisions should be involved in making them. And that there are always alternatives that can be considered.

The book outlines why risk assessment — the process currently relied on by governments and the private sector to make decisions — doesn't work, and goes on to explain why alternatives assessment is better and how to make the shift. Clearly written and easy to read, the book is full of convincing examples, including many relating to ecosystems and wildlife, that speak loudly for considering all possible alternatives before making decisions that will affect the health of humans and the natural environment.

This book is a must-read for all naturalists involved in decisions-making processes, as professionals or as volunteers, and for anyone concerned about the future of life on this planet.

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Scientific Method for Ecological Research

By E. David Ford. 2000. Cambridge University Press, Cambridge. 564 pp., illus. Cloth U.S. $10; paper U.S. $49.95

Dr. Ford, professor, College of Forest Resources, University of Washington, carves out, in exemplary fashion, a philosophy of ecological research. The philosophical exploration of the "hard" physical sciences as the paradigmatic sciences introduced assumptions as to what makes "good science," but it has become evident that certain of these assumptions are questionable or even false when it comes to the biological sciences and ecology. The philosophy of the physical sciences has created a "storybook scientist" who is considered specialized, reductionist, scientifically objective, rigorous, experimental, predictive, and essentially value-free. For Professor Ford, such a description is a caricature. Ford eschews any scientific method which defies particular techniques, a particular form of scientific reasoning, asserts that certain questions are more worthwhile than others, or assumes that questions must be asked in specific ways. For the author, the scientific method is not an immutable, monolithic process characterized by true and tried roadsides, but a creative process in which these roadsigns may take many and varied forms depending on the particular research question at hand.

Written with the graduate student and aspiring scientist in mind, Ford's weighty tome is broken down into four main sections; an analytical framework for conducting research, the basis for scientific inference and theory development in ecology, the social dimensions of research, and finally the presentation of a methodology for developing ecological theory, his so-called progressive synthesis. Making explicit how ecologists think in their research is his overarching goal. Of significance to Ford is a recognition of the unique features of ecological research which demand a research methodology different from that assumed for the physical sciences. Of particular concern is the open or partially open nature of ecological systems, the probabilistic nature of many ecological concepts, the inherent variability of ecological data, and problems of multiple causality. All of these factors pose greater difficulties in measurement and concept development, conditions for scientific inference, and the basis for theory acceptance or refutation when compared to controlled, laboratory conditions common to the physical sciences.

Ford's pedagogically refined review of the diverse forms of scientific reasoning and philosophical assumptions grounding scientific research is exhaustive and brimming with insight. Lack of space prevents the consideration of many critical issues, but attention to a select few is profitable. Particular emphasis is placed by Ford on the critical analysis of concepts and propositions, both of which

will act as the foundation of research. What is known (axioms), what one wishes to know (postulates), and how one intends to collect data that will assess postulates (data statements) are critical first steps in research. The clarification of ecological concepts is important as well. Ecology often focuses on what Ford terms integrative concepts (e.g., stability, ecological integrity, resilience), theoretical constructs about ecological organization that defy direct measurement and demand synthesis from a variety of system studies. Caution is directed to the uncritical use of statistical inference as the sole assessment of postulates. Highly significant is the notion of theory domains which define the boundaries within which a particular theory may or may not operate, effectively rendering ecological theory development very complex. Of significance as well is the notion that both measurement and experiment are essentially an art. Even when precise and accurate, all measurements by definition are abstracts in that they represent the object of interest, but are not the things themselves. Ford refutes the notion that Popperian falsification can be used as the basis for theory change, citing evidence to show that the rational basis for theory acceptance or rejection is much more complex.

The reader is introduced to the "subjective" or sociological dimensions of science. Science is presented as not simply an automated, invariant or determined process, but as a human activity undertaken by men and women acting as bearers of wisdom, passion, faults and foibles seemingly no more or no less than the "average citizen." Ford addresses such issues as scientific fraud, the publication process, peer-review, the significance of gender, and the role of scientists in developing public policy. Social processes are viewed as significant in determining which questions or research problems are considered important, which group will receive funding resources and precisely how research questions are formulated and pursued.

A popular view of science may assume that the scientific enterprise is a wholly "objective" process to which the particular investigator simply submits. Professor Ford returns a human face to science emphasizing the role of creativity, choice, probabilities, the art of science, plurality of logical reasoning and methodological ideals, a distancing from *a priori* philosophical assumptions. This by no means weakens the scientific enterprise, but rather re-introduces a rigorous and critical attitude in posing scientific problems and developing an adequate procedure of assessment. In doing this, Professor Ford ennobles human scientific activity by calling explicit attention to the pattern of scientific reasoning.

JOHN MCCARTHY, S. J.

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MISCELLANEOUS

The Last Great Sea: A Voyage through the Human and Natural History of the North Pacific Ocean

By T. Glavin. 2000. David Suzuki Foundation and Greystone Books, Douglas & McIntyre Publishing Group, Vancouver/Toronto. 244 pp.

This book belongs in every conservationist's bookshelf, to say the least. As D. Suzuki describes very convincingly in the foreword, the environment of today's North Pacific is characterized by its loss of (fish) species and its wipe-out of protein assemblages. The collapse of Sockeye Salmon is only one of many sad examples, many more exist: Steller's Sea Cow, Spectacled Cormorant, Dwason's Caribou (Queen Charlotte Islands), and even plant species like Tobacco (Queen Charlotte Islands). Other species like Walruses, Sea Otters, and Fur Seals have barely survived until now.

The first chapter starts slowly but allows a very solid overview about historical and archaeological facts. After Chapter 2, nobody can deny anymore the environmental disaster and mis-management of the North Pacific and coastal British Columbia. Nevertheless, the author convinces the reader that the North Pacific still is THE largest fish producer in the world. "*As in aboriginal fisheries, mythology played a part in industrial fisheries management, especially the myth of a superabundant ocean and the all-powerful capability of science and technology to fix the messes made by hydroelectric dams, lousy forestry practices and overfishing*". The governmentally encouraged Merganser Control and Bear Shooting Programs designed for the sake of Salmon Protection prove this citation very well. Galvin strongly eliminates all illusions on how to heal the problem of overfishing. For instance, he shows that S. Livingstone's widely followed idea of Fish Hatcheries does not produce more salmon, but instead takes away funds and harms natural salmon stocks since they simply replace the last remaining and struggling stocks with poorly adjusted new ones; Gavin's arguments are also strong against

Salmon Farming; e.g., it contributes to the closure of marine fisheries for wild salmon, and it requires 3 kg of fish to produce 1 kg of salmon.

All Pacific salmon species are discussed: Chum, Sockeye, Pink, Coho, Steelhead, Masu and Amago. Of major interest is in this regard the scientific discussion around the taxonomy of salmon; e.g., Steelhead (classified until 1980s as Trout). The author brilliantly points out the implications of the religious-based and somewhat outdated taxonomical system by Carl von Linné, and how this affects the species management by national governments (provincial and federal) on an international level even (Canada vs. U.S.A).

The backwardness and failure of fishery laws are shown by outlining that the first salmon-fishing regulations for the Fraser River was a simple word-for-word replication of fishing regulations on English Rivers. At that time, Canada's external affairs jurisdiction was still controlled by the British, which affects the Canada-U.S. salmon treaty concluded 1930s and renewed in 1985. In addition, Galvin shows that Canadian and U.S. fishery scientists significantly differed in their stock assessment results for the same species in the same waters even; consequently, so did the management and political agendas. This is the classical picture of "mixed-stock" fisheries, which also threatens small salmon runs.

The author reports the incidental death of 50 000 marine mammals and 500 000 seabirds due to driftnet fishery activities in the North Pacific; marine (plastic) pollution comes with it. Despite the well shown failure of a European and Western approach dealing with the North Pacific fisheries, domestic Japanese, and Native fisheries seemed to work well and sustainable. Galvin shows the magnitude of "pre-contact" fishery for salmon by natives, which was even comparable with levels of commercial fisheries from this century. Some readers might find that the book slightly follows stereotypical views of the noble native.

A very strong point in this book is how the North Pacific and its fauna is linked with the "hinterland": Old-growth rainforest, landscape and Bald Eagles. This needs to be considered in the light that resident Killerwhales in British Columbia are among the most contaminated cetaceans of the world.

A very complete picture of the North Pacific is portrayed by fully considering the Russian influence and history. The book outlines well that Russian settlers did much better than the western type of colonization (a point that might be put in doubt for the Kodiak Islands at least). The Russian-American Company was much more relevant in the history of North Pacific settlements and explorations than the Hudson Bay Company (HBC). But nevertheless, as with the HBC, the Russian quest for the North Pacific had the same motivation: central European pelt resources were already overhunted!

Regarding the marine ecology of the North Pacific, the importance of the Aleutian low, Pacific currents, and El Nino are fully described. This ecosystem is driven by 'regime changes', which calls for a dynamic management. The author outlines this very well by presenting the ground-breaking work from Russian Scientist T. Baranov, but also from Bill Ricker ("Ricker curve") and others at the Pacific Biological Station; e.g., G. McFarlane and D. Beamish. A quote from the book says it all: Understanding catch statistics is like "*reading a single faded and crumbling onionskin page from an early draft of Wagner's Tannhaeuser, in a dimly lit room*". Another quote of the book and taken from the U.N. Code of Conduct for Responsible Fisheries states, in part, that "*the absence of adequate scientific information should not be used as a reason for postponing or failing to take conservation and management measures*". Well said.

The chapters on anthropology and human history of the North Pacific and how the Russians, Asians, and Natives settled and explored the North Pacific are on the same level than high-caliber books as *Guns, Germs and Steel* by J. Diamond. Just to name some highlights, Glavin mentions how natives grew Arrowhead and potatoes, he cites the work of the Russian Anthropologist S. Fedorova, and he documents that Hawaiians, Japanese, Chinese and Russians presented a major group of settlers. In addition, the book reports a lot of British Columbian and Vancouver history and puts Canada in the context of the overall Pacific.

Despite the fact that whaling, sealing, and eating dolphins are as old as the human history of the North Pacific, whale watching (starting as early as 1907) has already produced more profit than commercial whaling ever did for western North America. Greenpeace started in Vancouver; it "was born in the blood of whales". Nevertheless, the author shows that already in the 19th century the pelagic seal hunt provoked the first great international controversy about the overharvesting of the world's marine mammals. It resulted in the international milestone contract ('fur seal treaty') of 1911 between Russia, Japan, Canada and U.S.A.

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NEW TITLES

Zoology

Animal ecology. 2001. By C. Elton. University of Chicago Press, Chicago. xvii + 209 pp., illus. U.S.$20.

*__A birder's guide to metropolitan areas of North America.__ 2002. Edited by P. Lehman. American Birding Association, Colorado Springs. iv + 508 pp., illus.

†__The birds of heaven: travels with cranes.__ 2001. By P. Matthiessen. Greystone Books, Douglas and McIntyre, Vancouver. xv + 349 pp., illus. $36.95.

*__The complete guide to the birds of Europe.__ 2000. By K. Mullarney, L. Svsnsson, D. Zetterstrom, and P. J. Grant. Princeton University Press, Princeton. 399 pp., illus. U.S.$49.50.

†__Conversations with an eagle: the story of a remarkable relationship.__ 2002. By B. Cox. Greystone Books (Douglas and McIntyre), Vancouver. 288 pp. $22.95.

†__Coral reef fishes.__ 2002. By E. Lieske and R. Myers. Revised edition. Princeton University Press, Princeton. 400 pp., illus. U.S.$24.95.

*__The Cuban treefrog in Florida.__ 2001. By W. E. Meshaka, Jr. University Press of Florida (Canadian distributor Scholarly Book Services, Toronto). xxiii + 191 pp., illus.

*__Dinosaurs: the encyclopedia, supplement 2.__ 2002. By D. F. Glut. McFarland, Jefferson, North Carolina. x + 685 pp., illus. U.S.$75.

__The family butterfly book: projects, activities, and a field guide to 40 favorite North American species.__ 2001. By R. Mikula. Storey Books, Pownal, Vermont. x + 166 pp., illus. Cloth U.S.$29.95; paper U.S.$16.95.

†__Geographic variation in size and shape of savannah sparrows *(Passerculus sandwichensis)*.__ 2001. By J. D. Rising. Cooper Ornithological Society, Camarillo, California. 65 pp., illus. U.S.$7.

__The grizzly almanac.__ 2001. By R. H. Busch. Lyon Press, New York. 240 pp., illus. U.S.$29.95.

*__Guia de las aves de Espana.__ 2000. By E. de Juana and J. M. Varela. Lynx Edicions, Barcelona. 223 pp., illus. 15 Euros.

*__Handbook of the birds of the world: volume 7: jacamars to woodpeckers.__ 2002. Edited by J. de Hoyo, A. Elliot, and J. Sargatal. Lynx Edicions, Barcelona. 613 pp., illus. U.S.$185.

*__National Audubon Society guide to marine mammals of the world.__ 2002. By R. R. Reeves, B. S. Stewart, P. J. Clapham, and J. A. Powell. Alfred A. Knopf, New York. 527 pp., illus. U.S. $26.95. Canadian distributor Random House, Toronto. $39.95.

__Neotropical treeboas: natural history of the *Corallu hortulanus* complex.__ 2002. By R. W. Henderson. Kreiger Publishing, Melbourne, Florida. 228 pp., illus. U.S.$44.50.

__New animal discoveries.__ 2001. By R. Orenstein. Twenty-First Century Books, New York. 64 pp., illus. U.S.$25.

__Noises in the night: the habits of bats.__ 2001. By D. Kovacs. Steck-Vaughn, Austin, Texas. 48 pp., illus. U.S. $25.

__Pheasants, partridges, and grouse.__ 2002. By S. Madge and P. McGowan. Princeton University Press, Princeton. 480 pp., illus. U.S. $49.50.

__A pocket guide to reptiles and amphibians of Alberta.__ 2002. By A. P. Russell and A. M. Bauer. Red Deer Press, Calgary. 260 pp., illus. $24.95.

__Sea soup: zooplankton.__ 2001. By M. M. Cerullo. Tilbury House, Gardiner, Maine. 40 pp., illus. U.S. $16.95.

†__Sharks.__ 2002. By A. and A. Ferrari. Firefly Books, Willowdale, Ontario. 256 pp., illus. $24.95.

__Tadpoles of south-eastern Australia: a guide with keys.__ 2002. By M. Austis. Kreiger Publishing, Melbourne, Florida. 281 pp., U.S.$44.50.

*__Tales from the underground: a natural history of subterranean life.__ 2001. By D. W. Wolfe. Perseus, Cambridge, Massachusetts. x + 223 pp., illus. U.S.$26.

†__Thunder on the tundra: Inuit qaujimajatugangit of the Bathurst caribou.__ 2002. By N. Thorpe, N. Hakongak, S. Eyegetok, and the Kitikmeot Elders. Available through Natasha Thorpe, 231 Irving Road, Victoria, B.C. V8S 4A1. 208 pp., illus. $42.

†__Turtles and tortoises.__ 2002. By V. Ferri. Firefly Books, Willowdale, Ontario. 256 pp., illus. $24.95.

__Why elephants have big ears: understanding patterns of life on earth.__ 2001. By C. Lavers. St. Martins, New York. 288 pp., illus. U.S.$23.95.

Botany

*__Dictionary of the fungi.__ 2001. By P. M. Kirk, P. F. Cannon, J. C. David, and J. A. Staples. CAB International (distributed by Oxford University Press, Cary, North Carolina). xi + 655 pp., illus.

__A field guide to water and wetland plants of the prairies.__ 2002. By H. Lahring. Red Deer Press, Calgary. 192 pp., illus. $18.95.

†__Forest dynamics and disturbance regimes: studies from temperate evergreen — deciduous forests.__ 2002. By L. E. Frelich. Cambridge University Press, New York. ix + 266 pp., illus. U.S.$70.

__Harmful algal blooms on the North American west coast.__ 2001. Edited by R. Ralonde. Alaska Sea Grant College Program, Fairbanks. 73 pp. U.S$10.

†**New world botany.** 2001. By R. H. Peterson. Koeltz Scientific Books, Koenigstein, Germany. xv+ 638 pp., illus. Cloth Euro 93; paper Euro 62.

Wildflowers around the year. 2001. By H. Ryden. Clarion, New York. 90 pp., illus. U.S.$17.

Wild flowers of field and slope. 2002. By L. Clark. Harbour Publishing, Madeira Park, British Columbia. 80 pp., illus. $9.95.

Environment

The B.C. roadside naturalist. 2002. By R. Cannings and S. Cannings. Greystone Books (Douglas and McIntyre, Vancouver). 240 pp., illus. $29.95.

The beachcombers's guide to seashore life of California. 2002. By J. D. Sept. Harbour Publishing, Madeira Park, British Columbia. 300 pp., illus. CAN $28.95; U.S.$17.95

†**Conserving living natural resources in the context of a changing world.** 2002. By B. J. Weddell. Cambridge University Press, New York. xvi + 426 pp., illus. U.S.$35.

Evolution's workshop: God and science on the Galapagos Islands. 2001. By E. J. Larson. Basic Books, New York. 322 pp., illus. U.S.$27.50.

The functional consequences of biodiversity: empirical progress and theoretical extensions. 2002. Edited by A. P. Kinzig, S. W. Pacola, and D. Tilman. Princeton University Press, Princeton. 392 pp., illus. Cloth U.S.$75: paper U.S.$29.95.

Green phoenix: restoring the tropical forest of Guanacaste, Costa Rica. 2001. By W. Allen. Oxford, New York. 310 pp. U.S.$35

†**Introduction to conservation genetics.** 2002. By R. Frankham, J. D. Ballou, and D. A. Briscoe. Cambridge University Press, New York. xi + 617 pp., illus. Cloth U.S. $130; paper U.S.$50.

†**Life at the limits: organisms in extreme environments.** 2002. By D. A. Wharton. Cambridge University Press, New York. xi + 307 pp., illus. U.S.$25.

*__Making parks work: strategies for preserving tropical nature.__ 2002. Edited by J. Terborgh, C. van Schaick, L. Davenport, and M. Rao. Island Press, Washington. xix + 511 pp., illus. Cloth U.S.$65; paper U.S.$32.50.

Marine community ecology. 2001. Edited by M. D. Bertness, S. D. Gaines, and M. E. Hay. Sinauer, Sunderland, Massachusetts. 550 pp., illus. U.S.$59.95.

†**Multitrophic level interactions**. 2002. Edited by T. Tschrntke and B. A. Hawkins. Cambridge University Press, New York. vii+274 pp., illus. U.S.$75.

*__Politics of the wild: Canada and endangered species.__ 2001. Edited by K. Beazley and R. Boardman. Oxford University Press Canada, Toronto. x + 254 pp., illus. $27.95.

†**Reef life.** 2002. By A. and A. Ferrari. Firefly Books, Willowdale, Ontario. 288 pp., illus. $24.95.

†**Spread sheet exercises in conservation biology and landscape ecology.** 2002. By T. M. Donovan and C. W. Welden. Sinauer Associates, Sunderland, Massachusetts. xi + 464 pp., illus. U.S.$5.

†**Spread sheet exercises in ecology and evolution.** 2002. By T. M. Donovan and C. W. Welden. Sinaeur Associates, Sunderland, Massachusetts. xi + 556 pp., illus. U.S.$5.

†**Summary of knowledge acquired in northern environments from 1970 to 2000.** 2001. By G. Hayem. Hydro-Quebec, Montreal. 110 pp., illus. Free.

*__Two hundred years of ecosystem and food web changes in the Quoddy Region, Outer Bay of Fundy.__ 2002. By H. Lotze and I. Milewski. Conservation Council of New Brunswick, Fredericton.

The tropical rainforest: explore the natural world of the rainforest swamplands and the interior. 2001. By G. Cheshire. Crabtree, New York. 39 pp., illus. U.S.$18.

Visions of the wild: a voyage by kayak around Vancouver Island. 2001. By M. Coffey and D. Goering. Harbour Publishing, Madeira Park, British Columbia. 182 pp., illus. $36.95.

†**Weird nature: an astonishing exploration of nature's strangest behavior.** 2002. By J. Downer. Firefly Books, Willowdale. 156 pp., illus. Cloth $35; paper $19.95.

Wild solutions: how biodiversity is money in the bank. 2001. By A. Beattie and P. Ehrlich. 240 pp. U.S.$25.95.

Miscellaneous

†**Catalogue of meetings 1988 to 2001 McIlwraith Field Naturalists.** 2002. By W. W. Judd. Phelps Publishing, London, Ontario. 28 pp. $8.

*__Cheltenham in Antarctica.__ 2002. By D. M. Wilson and D. B. Elder. Reardon Publishing, Cheltenham, England. 140 pp., illus. E9.99.

†**Common and contested ground: a human and environmental history of the northwest plains.** 2002. By T. Binnema. University of Oklahoma Press, Norman. xvi + 263 pp., illus. U.S.$29.95.

*__The one culture: a conversation about science.__ 2001. Edited by J. A. Labinger and H. Collins. University of Chicago Press, Chicago. xii+ 329 pp. U.S.$18.

*__On her own terms: Annie Montague Alexander and the rise of science in the American West.__ 2001. By B. R. Stein. U. California P., Berkeley. xvii + 380 pp., illus. U.S.$35.

Books for Young Naturalists

About amphibians: a guide for children. 2001. By C. Sill. Peachtree, Atlanta. 40 pp., illus. U.S.$14.95.

Animals nobody loves. 2001. By S. Simon. North-South Books, New York. 48 pp., illus. U.S.$15.95.

Bears. 2001. By D. Ferte, M. Reddy, and E. D. Stoops. Sterling, New York. 80 pp., illus. U.S.$17.95.

Caimans. 2001. By S. Dollar. Raintree Steck-Vaughn, Austin. 32 pp., illus. U.S.$23.

Dolphins. 2001. By J. Vogel. NorthWord Press, Minnetonka, Minnesota. 48 pp., illus. U.S.$7.98.

Global Warming: the threat of earth's changing climate. 2001. By L. Pringle. North-South Books, New York. 48 pp., illus. U.S.$16.95.

Kids care for the earth. 2002. By G. Thompson. National Geographic Society, Washington. 32 pp., illus. U.S.$41.95 (pack of 6).

Manatees. 2001. By K. Feeney. NorthWord Press, Minnetonka, Minnesota. 48 pp., illus. U.S.$7.95.

100 award – winning science fair projects. 2001. By G. Vecchione. Sterling, New York. 208 pp., illus. U.S.$21.95.

Protecting our planet : animal watch. 2001. By R. Few. DK Publishing, New York. 60 pp., illus. U.S.$16.95.

Rain forest. 2001. By E. Greenwood. DK Publishing, New York. 48 pp., illus. U.S.$9.95.

Recycling and reuse: our impact on the planet. 2002. By R. Bowden. Raintree Steck-Vaughn, Austin, Texas. 64 pp., illus. U.S.$18.98.

The seashore. 2001. By A. Wilkes. Kingfisher, New York. 32 pp., illus. U.S.$11.95.

Sharks. 2001. By L. Evert. NorthWord Press, Minnetonka, Minnesota. 48 pp., illus. U.S.$7.95.

Song birds: the language of song. 2001. By S. A. Johnson. Carolrhoda, Minneapolis. 48 pp., illus. U.S.$23.95.

Spiny sea stars. 2001. By C. Zuchora-Walske. Lerner, Minneapolis. 32 pp., illus. U.S.$21.95.

Sure-to-win science fair projects. 2001. By J. Rhatigan. Lark Books, New York. 128 pp., illus. U.S.$21.95.

*Assigned for review
†Available for review.

News and Comment

Sea Wind: Bulletin of Ocean Voice International 5(1/2) December 2001

This special commemorative edition combines two issues between its covers and is edited by Marcia Campbell and Noel Alfonso. *Sea Wind* 15(1): 1-37, was the last issue Don E. McAllister was working on before his death 17 June 2001, and contains: A special notice from the editors; Fire Shrimp successfully cultured in Sri Lanka; A scientific consensus on marine reserves; Filipino fisher-folk fighting to benefit from marine biological riches; Free trade and sovereignty to protect rights of coastal communities & fishers; Satellite data helps save coral reefs; Selective fishing recommendations in Canada; Mapping life in the world's oceans; Ocean Voice International 2001 Annual General Meeting; Ocean Voice International Annual Report; Sea News. *Sea Wind* 15(2): 38-64, is dedicated to Don McAllister and contains: Memorial cover page "In memory of Don" a tableau of scleractinian corals by Roelof Idema; Ode to Grampa; Friends write in memory of Don; Dedication article: model citizen of the world; Curatorial and research contributions - Museum of Nature; Dedication article: Is bottom trawling scorched-earth fishing; Kid's korner; Tatay Don McAllister: Haribon Foundation's empowering partner; Ocean Voice International membership form.

For membership rates contact Ocean Voice International, Box 37026, 3332 McCarthy Road, Ottawa, Ontario K1V 0W0; Telephone (613) 721-4541; Fax (613) 721-4562; Office Manager at e-mail: oceanvoice.superaje.com; home page: http://www.ovi.ca.

Biodiversity: Journal of Life on Earth 3(1) February 2002

Contents: Teaming up to conserve the biodiversity of Western Kenys (Eusebius J. Mukhwana) — Some reflections on the work of Don E. McAllister (Ted Mosquin) — Marine biodiversity of of Canada: Threats and conservation solutions — Black widow spiders: An outline of diversity (Charles D. Dondale) — The Giant Jamaican Swallowtail (*Papilio homerus* F.) — Going, going... (Peter W. Hall) — Forum: Omission of Biodiversity measurement and human population issues - shocking! (Don Kerr) -- Editor's Corner (Ted Mosquin) — Species by species [Chocolate, *Theobroma cacao*] — Biodiversity News — Book Reviews — Announcements.

The new editor of *Biodiversity* is Dr. Ted Mosquin; Catherine Ripley remains as Managing Editor. *Biodiversity* is published by The Tropical Conservancy, 94 Four Seasons Drive, Ottawa, Ontario K2E 7S1 Canada, e-mail: tropical@synapse.net;
URL: http://www.synapse.net/~tropical

The Boreal Dip Net: Newsletter of the Canadian Amphibian and Reptile Conservation Network 6(1) December 2001

This issue highlights the CARCNET meetings held in Prince Edward Island in 18-22 October 2001. [List of abstracts from the meeting is available on the website: http:\www.carcnet.ca/]. Contents: Editor's note [Kerrie Serben]; Report from the Chair [Christine Bishop]; CARCNET Resolution to help marine trutles in Canada; 2001 CARCNET Award Winners: The Blue Racer Award [Francis R. Cook]; Silver Salamander Awards [Nature Trust of New Brunswick for establishment of Hyla Park (Fredericton) and Ducks Unlimited for their Small Marsh Program]; DigitalFrog International/CARCN Scholarship [Shana Truant: A comparison of four different salamander sampling techniques and a study of salamander populations that reside in riparian reserves in Ontario's mixedwood forests]; Student Platform presentations; Abstracts/Lecture notes from Keynote Speakers: Sherman Bleakney, Francis R. Cook, Michael C. James; Field trip - Revisiting Old Study Sites in PEI [Shana Truant]; The rare and secretive Sharp-tailed Snake [David Cunnington]; Fracine the Poster Frog ["Its not easy being green": Kejimkujik National Park: Peter Hope]; CARCNET List of Directors for 2001-2002.

Recovery: An Endangered Species Newsletter (19) January 2002

Published by the Canadian Wildlife Servis this issue contains: Recovery Highlights: Tracking turtles; Protecting habitat; Taking flight; Saving Ontario's mussels [David Wylynko]; Special Report: Endangered Species Recovery Fund: Supporting a diverse array of projects; Bowhead whale strategy releasd: Long-term conservation, ecosystem approach planned for eastern arctic population; Wood Bison recovery plan approved; Scientists launch beluga recovery; Caribou committee proposed; Recovering Newfoundland plants; Updates: Workshop held; Report released; Assessing soecies; Monitoring migrations: Ham operators assist scientists in search for wild species in migration; Researchers map biodiversity; New findings in swan research; New publications; Awards; Site seeing; Featured Species: Rador reveals bird's secretive behaviour [Marbled Murrelet].

Contact: Recovery, Canadian Wildlife Service, Environment Canada, Ottawa, Ontrio K1A 0H3.
Web site: www.cws-scf.ec.gc/recovery/archive.html

RENEW: National Recovery Plan Number 21: The Wood Bison, *Bison bison athabascae*

The Recovery of Nationally Endangered Wildlife [Canada] has issued its "National Recovery Plan for the Wood Bison, *Bison bison athabascae* as Plan Number 21, October 2001. 50 pages. It was prepared by a team consisting of C. Cormack Gates, University of Calgary; Robert O. Stephenson, Alaska Department of Fish and Game; Hal W. Reynolds, Canadian Wildlife Service, Environment Canada; C. G. Van Zyll de Jong [deceased May 1997, formerly mammalogist, Canadian Museum of Nature]; Helen Schwantje, British Columbia Ministry of Environment, Lands and Parks; Manfred Hoefs, Yukon Department of Renewable Resources; John Nishi, Northwest Territories, Wildlife and Economic Development; Normand Cool and Jane Chisholm, Parks Canada Agency; Adam James, Alberta Fish and Wildlife Service, Sustainable Resource Development; Bill Koonz, Manitoba Department of Natural Resources. Copies are available from Recovery Secretariat, c/o Canadian Wildlife Service, Environment Canada, Ottawa, Ontario K1A 0H3; Tel 819-953-1410; Fax 819-994-3684.

Alberta Wildlife Status Reports numbers 37, 38, 39

The Fisheries and Wildlife Management Division of the Alberta Natural Resource Status and Assessment Branch, Alberta Environmental Protection, has released new Wildlife Status Reports. The Series Editor is Sherry Frazer (37), Sherry Frazer and Robin Gutsell (38 and 39); the Senior Editor for (37) is Isabelle M. G. Michaud; and the illustrations are by Brian Huffman for all three. For a listing earlier numbers in the series, see *The Canadian Field-Naturalist* 112(1): 169 for 1-11; 113(2): 311 for 12-17; 113(4): 686 for 18-21; 114(1): 151 for 22-25; 115(2): 390 for 26-31; 115(3): 000 for 32-36. Recent reports issued in 2001 are:

37. Status of the Grizly Bear (*Ursus arctos*) in Alberta, by John L. Kansas. 43 pages.
38. Status of the Wood Bison (*Bison bison athabascae*) in Alberta, by Jonathan A. Mitchell and C. Cormick Gates. 32 pages.
39. Status of the Bull Trout (*Salvelinus confluentus*) in Alberta, by John R. Post and Fiona D. Johnson. 40 pages.

For copies contact the Information Centre - Publications Alberta Environment/Alberta Sustainable Resource Development, Fish and Wildlife Division, Main Floor, Great West Life Building, 9920 – 108 Street, Edmonton, Alberta T5K 2M4 Canada (telephone: (780) 422-2079), OR Information Service Alberta Environment/Sustainable Resource Development, #100, 3115 – 12 Street NE, Calgary, Alberta T2E 7J2, Canada (telephone: (403) 297-3362); web site: http://www3.gov.ab.ca/srd/fw/status/index.html.

Ontario Natural Heritage Information Centre Newsletter 6(1) Winter 2002

Contents of this 20 page issue: Great Lakes Ecoregional Planning Project — NHIC Prepares Ontario's first "General Status of Wild Species" report — NHIC Assists with the Georgian Bay Coast Project — Kawartha Highlands Update — Zoology: Species at Risk Biologists Assist with Surveys of Threatened Fish Species — NHIC Hosts the First Great Lakes Odonata Meeting — Botany: 2001 Botanical Highlights — Community Ecology: Rare Vegetation of Ontario: Database Cliffs of Northwestern Ontario — News and Notes: NHIC Establishes New Partner Agreement — NHIC Prepares Report on the Occurrence of Species at Risk in OMNR Districts — Trent University-NHIC Internships in Conservation Biology — NHiC Participates in First Pelee Island Endangered Species Festival — Updates to the OMNR and COSEWIC Lists of Species at Risk — "Bioconservation and Systematics" Proceedings Now Available — Farewell to Jarmo Jalava — Book Reviews — Focus on Gordon Wichert — Greetings from NIHC's New Coordinator — NHIC Staff List.

Mailing address for Natural Heritage Information Centre: 300 Water Street, 2nd Floor, North Tower, P.O. Box 7000, Peterborough, Ontario K9J 8M5, Canada.
Web page: http://www.mnr.gov.on.ca/MNR/nhic.html

Marine Turtle Newsletter (95)

The January 2002 issue, 36 pages, contains: GUEST EDITORIAL: The swampland of sea turtle conservation: in search of a philosophy — ARTICLES: Status of the sea turtle trade in Alexandria's fish market — Direct carapacial attachment of satellite using orthopedic bioabsorbable mini-anchor screwws on Leatherback Turtles in Culebra, Puerto Rico — NOTES: The reproductive status of marine turtles nesting in the Cayman Islands: work in progress — occurrence terminology for marine turtles — sea turtle research and conservation project in Cipara, Paria Peninsula, Sucre State, Venezuela: Preliminary results of the 2000 nesting season — Project update: University Progject for the study of conservation of Cuban sea turtles: completion of year 3 — ANNOUNCEMENTS — BOOK REVIEWS — NEWS & LEGAL BRIEFS — RECENT PUBLICATIONS.

The Marine Turtle Newsletter is edited by Brendan J. Godley and Annette C. Broderick, Marine Turtle Research Group, School of Biological Sciences, University of Wales, Swansea, SA2 8PP Wales, United Kingdom; e-mail

MTN@swan.ac.uk; Fax +44 1792 295447. Subscriptions to the MTN and donations towards the production of MTN and its Spanish edition NTM [Noticiero de Tortugas Marinas] should be sent to Marine Turtle Newsletter c/o Chelonian Research Foundation, 168 Goodrich Street, Lunenburg, Massachusetts 01462 USA; e-mail RhodinCRF@aol.com; fax + 1 978 582 6279. MTN web-site is: <http://www.seaturtle.org/mtn/>

Froglog: Newsletter of the Declining Amphibian Populations Task Force (49)

Number 49, February 2002, contains: Crisis less severe for Po Valley Spadefoot *Pelobates fuscus insubricus* (Vincenzo Ferri Italian DAPTF Working Group & Toads Project) — Effects of Habitat Disturbance on a Frog Community in a Mexican Dry Forest (Ireri Suazo-Ortuno) — Amphibian Monitoring in Africa (Cote d'Ivoire, Kenya) and Asia (Borneo) (from Global Amphbian Diversity Anaysis Group) — Amphibian decline in the Kariba Wilderness Area, Zimbabwe (Peter Taylor) — Froglog Shorts — Publications of Interest.

Froglog is the bi-monthly newsletter of the Declining Amphibian Populations Task Force of The World Conservation Union (IUCN)/Species Survival Commission (SSC) and is supported by The Open University, The World Congress of Herpetology, The Smithsonian Institution, and Harvard University. The newsletter is Edited by John W. Wilkinson, Department of Biological Sciences, The Open University, Walton Hall, Milton Keynes, MK7 6AA, United Kingdom; e-mail: daptf@open.ac.uk. Funding for *Froglog* is underwritten by the Detroit Zoological Institute, P. O. Box 39, Michigan 48068-0039, USA.

The 124th Annual Business Meeting of The Ottawa Field-Naturalists' Club: 7 January 2003

The 124th Annual Business Meeting of The Ottawa Field-Naturalists' Club will be held in the auditorium of Victoria Memorial Museum (Canadian Museum of Nature), McLeod and Metcalfe streets, Ottawa, on Tuesday 7 January 2003 at 7:30 p.m. (19:30 h). The Council for 2003 will be elected at this meeting and a brief review of the activities during 2002 will be given, as well as a statement of the Club's finances.

KEN ALLISON
Recording Secretary

Call for Nominations: The Ottawa Field-Naturalist's Club 2003 Council

Candidates for Council may be nominated by any member of The Ottawa Field-Naturalist's Club. Nominations require the signature of the nominator and a statement of willingness to serve in the position for which nominated by the nominee. Some relevant background information on the nominee should also be provided.

FENJA BRODO
Chair, Nominating Committee

Call for Nominations: The Ottawa Field-Naturalists' Club 2002 Awards

Nominations are requested from members of The Ottawa Field-Naturalists' Club for the following: Honorary Membership, Member of the Year, George McGee Service Award, Conservation Award: Member, Conservation Award: Non-member, and the Anne Hanes Natural History Award. Descriptions of these awards have appeared in *The Canadian Field-Naturalist* 113(4): 689. With the exception of nominations for Honorary Member and Conservation Award: Non-member, all nominees must be members of The Ottawa Field-Naturalist Club in good standing.

IRVIN BRODO
Chair, Awards Committee

Letters to the Editor:

Blastomycosis in Free Ranging Wolves, *Canis lupus*, on the North Shore of Lake Superior, Ontario — A response to P. Krizan

The July–September 2000 issue of the Canadian Field-Naturalist 114(3): 491–493 contained an article titled "Blastomycosis in a Free Ranging Wolf, *Canis lupus*, on the North Shore of Lake Superior, Ontario", authored by Mr. Peter Krizan. We regret that Mr. Krizan published the article without institutional or contractual approval of the researchers who collaborated in the collection, analyses, and interpretation of the data. We view the independent publication and appropriation of these results as an unprofessional assumption of the authorship and very serious breach of professional ethics. For the record, the research was conducted under federal and provincial permits issued to Dr. Paul Paquet as primary investigator. By common agreement that included Mr. Krizan; the study team had assigned senior authorship to Dr. Doug Campbell of OVC, Pathobiology, Ontario Region Wildlife Health Centre, University of Guelph. In alphabetical order, coauthors were Frank Burrows (Parks Canada), Anne Forshner (University of Alberta), Peter Krizan (Acadia University), Graham Neale (University of Montana), Paul Paquet (University of Calgary), and Keith Wade (Parks Canada).

The information included in Mr. Krizan's initial report is accurate but incomplete. We take this opportunity to expand the original note. Blastomycosis is a chronic fungal disease that affects the pulmonary system of humans and dogs, and occasionally other animals (Jungerman and Schwartzman 1972; Stroud and Coles 1980; Legendre et al. 1981; Thiel et al. 1995). The fungus is enzootic in Minnesota (Schlosser 1980) and Wisconsin (Sarosi et al. 1979; McDonough and Kuzman 1980) but until now, had not been reported in other North American wolf populations. From 1995–1999, three adult radiocollared wolves from our study sample (n = 26) were diagnosed with Blastomycosis at the time of death, though only one (Krizan 2000) was determined to have died of the disease. One wolf (Spirit, male) was shot and another (Moon, female) killed by other wolves (Forshner 2000). The latter was in extremely poor condition and evidence at the site of her death suggested pack mates killed her. All three wolves occupied home ranges north of Pukaskwa National Park and were members of different packs. Recently, these wolves were shown to be genetically distinct from the Gray Wolves (*C. lupus*) occurring within Pukaskwa National Park (Wilson et al. 2000). Both types of wolves are known to occur in Minnesota and Wisconsin but the original reports of blastomycosis infections in these regions preceded genetic typing. Consequently, blastomycosis has not been unambiguously confirmed in both types of wolves.

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Forshner, S. A. 2000. Population dynamics and limitation of wolves (*Canis lupus*) in the Greater Pukaskwa Ecosystem, Ontario. M.Sc thesis, University of Alberta, Edmonton, Alberta, 129 pages.

Jungerman, P. F., and **R. M. Schwartzman**. 1972. Veterinary medical mycology. Lea and Febiger, Philadelphia, Pennsylvania, USA. 200 pages.

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Blastomycosis in a Free ranging Wolf, *Canis lupus*, on the North Shore of Lake Superior, Ontario — A reply to P. Paquet et al.

Paquet et al. report interesting results that add valuable information to the original note by Krizan 2000 and suggest that Blastomycosis is more prevalent than was originally thought and may not always be fatal. My note (Krizan 2000) was one finding of my Masters thesis that was started in 1993 and was completed and defended in 1997 (Krizan 1997). It should be noted that the additional data provided by Paquet et al. were collected after the completion of my thesis.

In both publications (Krizan 2000, 1997), I acknowledged the members and agency involved in the co-operative project for their role and participation. Parks Canada (Pukaskwa National Park) supported the Pukaskwa National Park Predator Prey Process Project (P5) through logistical support. In addition, many volunteers and other researchers working on different aspects of this project were involved to different degrees; those who had contributed directly to the collection of data were mentioned by name in the acknowledgment sections of Krizan 1997 and 2000. I once again acknowledge the role of some of the co-authors of Paquet et al. in the overall project and their recent contribution.

I was one of three students completing a Masters thesis from 1993 to 1997. The only agreement that I had with Parks Canada and/or P. Paquet, who was the principal investigator contracted by Parks Canada was that Parks Canada would supply the logistical support for my project and in return, I would collect, analyze and publish my results and make my thesis and raw data available to the Pukaskwa National Park office. I have fulfilled all of those responsibilities. During 1993 to 1997 I was an independent student with no contractual agreements with any of the co-authors of Paquet et al. I was the only one that analyzed data that was used in the Krizan 2000 publication except for the necropsy that was done by Dr. Doug Campbell (as was acknowledged). I had discussed Dr. Campbell's necropsy results with him and he provided me with relevant literature. To the best of my knowledge, the research results of the Masters thesis are owned by copyright and are not subject to institutional or contractual consent. My research interest was to describe the travel patterns of Wolves and how these movements were affected by human presence, activity, and landscape differences in and outside of Pukaskwa National Park. The case of blastomycosis was interesting in that infection by this fungus was probably due to the fact that this Wolf was a lone animal that exposed itself to areas by travelling in environments that may have had a higher probability of exposure to the fungal spores. Also interesting was the fact that the travel distances between locations diminished as the disease affected the ability of the Wolf to travel. To the best of my knowledge, I was the only person on the P5 project team that was interested in the spatial use of Wolves. As with any project, there are many people that are involved to various degrees and I've acknowledged those who had contributed directly to the collection of data.

Two of the co-authors of Paquet et al. were also students working on their theses of various but different topics. I am confused about the role and co-authorship of Miss Forshner. I met Miss Forshner once as I was leaving the project. I had never worked with her nor did I ever discuss authorship of publications. The implied consent to co-author any publication in the order that Paquet et al. suggest is incorrect.

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Krizan, P. 1997. The effects of human land development, landscape characteristics, and prey density on the spatial distribution of Wolves (*Canis lupus*) on the north shore of Lake Superior, Ontario. M.Sc. thesis, Acadia University, Wolfville, Nova Scotia. 108 pages.

Krizan, P. 2000. Blastomycosis in a free ranging lone Wolf, *Canis lupus*, on the north shore of Lake Superior, Ontario. Canadian Field-Naturalist 114: 491-493.

PETER KRIZAN

P.O. Box 1167 Iqaluit, Nunavut X0A 0H0 Canada

Received 5 December 2001

Advice for Contributors to *The Canadian Field-Naturalist*

Content

The Canadian Field-Naturalist is a medium for the publication of scientific papers by amateur and professional naturalists or field-biologists reporting observations and results of investigations in any field of natural history provided that they are original, significant, and relevant to Canada. All readers and other potential contributors are invited to submit for consideration their manuscripts meeting these criteria. The journal also publishes natural history news and comment items if judged by the Editor to be of interest to readers and subscribers, and book reviews. Please correspond with the Book Review Editor concerning suitability of manuscripts for this section. For further information consult: A Publication Policy for the Ottawa Field-Naturalists' Club, 1983. *The Canadian Field-Naturalist* 97(2): 231-234. Potential contributors who are neither members of *The Ottawa Field-Naturalists' Club* nor subscribers to *The Canadian Field-Naturalist* are encouraged to support the journal by becoming either members or subscribers.

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Please submit, **to the Editor**, in either English or French, **three** complete manuscripts **written in the journal style**. The research reported should be original. It is recommended that authors ask qualified persons to appraise the paper before it is submitted. All authors should have read and approved it. Institutional or contract approval for the publication of the data must have been obtained by the authors. Also authors are expected to have complied with all pertinent legislation regarding the study, disturbance, or collection of animals, plants or minerals. The place where voucher specimens have been deposited, and their catalogue numbers, should be given. Latitude and longitude should be included for all individual localities where collections or observations have been made.

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The Ottawa Field-Naturalists' Club

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The Canadian Field-Naturalist

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Cover: Logan Glacier and the St. Elias Mountains in Wrangell-St.Elias National Park and Preserve, Alaska. The site in the foreground is the locality of *Arabis calderi* G. A. Mulligan, which is new to Alaska, and also the collection locality of the mustards *Braya glabella* Richardson ssp. *glabella*, *Draba cinera* Adams, *D. incerta* Payson, *D. macounii* O. E. Schultz, *D. oligosperma* Hook. and *Lesquerella arctica* (Wormsk.) S. Wats. ssp. *arctica*, all of which were range extensions at this site. *Silene menziesii* Hook., *Carex filifolia* Nutt., and *Danthonia intermedia* Vasey were other range extensions from this locality. *See* article on notable vascular plants form Alaska by Mary B. Cook and Carl A. Roland, pages 192–304.

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Winter Habitat Selection at Three Spatial Scales by American Elk, *Cervus elaphus*, in West-Central Alberta

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Selection by American Elk (*Cervus elaphus*) at the landscape (2nd order), stand (3rd order), and site level (4th order) was examined in west-central Alberta from 1 December 1994 to 21 March 1995. At the landscape level, elk home ranges had a lower mean road density, but greater mean unimproved access density. Elk home ranges had smaller mean patch sizes and greater patch density. There was no significant selection on the basis of food and cover composition. At a stand level, elk used the grass/meadow habitat more than expected while all other habitat types were used in proportion to their availability. At a site scale, we attempted to distinguish habitat use for feeding and bedding. Feeding sites had a lower mean percent canopy closure, percent shrub cover, stem density and tree height, but a higher mean percent grass cover than bedding sites. Feeding sites were significantly closer to unimproved access than were bedding sites. Feeding sites had more grass cover and significantly less canopy closure, percent shrub cover, spruce, pine, and fir in the canopy, and lower tree height and stem density than the control plots. They were located significantly closer to unimproved access and farther from hiding cover. Bedding sites had a higher percent grass cover, less spruce, pine and fir in the canopy, and a lower stem density than the control plots. In terms of spatial attributes, elk exhibited no selection when choosing bedding sites. The need to examine habitat selection patterns at more than one scale is discussed

Key words: *Cervus elaphus*, American Elk, habitat, landscape, site, spatial scale, stand, Alberta.

Resource selection is an adaptive response of animals attempting to meet their life requirements and ultimately to increase fitness (Johnson 1980; Thomas and Taylor 1990; Manly et al. 1993). Choice of habitat is governed by a variety of factors including energy requirements, thermal conditions, reproductive requirements, and intra- and interspecific competition (Litvaitis et al. 1986; Morrison et al. 1992).

Johnson (1980) defined four levels or scales of habitat selection: (1) selection of a physical or geographical range, (2) selection of a home range within that geographical range, called landscape selection, (3) selection of habitat components within the home range, termed stand selection and (4) selection of food items at a particular feeding site. Lofroth (1993) expanded Johnson's (1980) fourth-order selection to include habitat components required for such activities as mating, calving, escaping predators and for shelter. We define this level of selection as site selection.

There are several possible outcomes to habitat studies conducted at multiple scales. Selection mainly at the landscape level is important in several species such as the Spotted Owl (*Strix occidentalis*). Hansen et al. (1993) concluded that landscape level habitat features describing old growth forests were the best predictors of spotted owl abundance. At the other end of the spectrum, a species may select habitat characteristics mainly at a site level. This may be the case for generalists who are able to utilize different local conditions found in a variety of landscapes (Pearson 1993). The probable outcome of multiple level habitat selection is a species selecting habitat characteristics at more than one scale. Lofroth (1993) determined that Marten (*Martes americana*) selected mature to old growth seral stage habitats within their home range (landscape level), while showing no preference for any habitat type, but avoided young seral stages, xeric habitat types and wetlands (stand level). At the site level, Marten selected structural characteristics that were different from the prevailing characteristics of the habitat type (Lofroth 1993). Selection at more than one scale may be complementary to each other or selection at one level may explain why it occurred at a higher level (Pedlar et al. 1997).

Previous research has suggested that habitat selection by elk (*Cervus elaphus*) has been governed by

forage, thermal cover and hiding cover requirements (Hersey and Leege 1976; Lyon 1979; Gates and Hudson 1981; Irwin and Peek 1983; Marcum and Scott 1985; Edge et al. 1987; McCorquodale 1987). These studies have examined selection at one specific level. We examined resource use by elk at the landscape (2nd order), stand (3rd order) and site level (4th order). The central hypothesis was that elk select habitats for foraging, thermal cover and hiding cover at more than one scale. Our first objective was to determine if elk selected home ranges based on habitat components. Our second objective was to determine if elk selected specific habitat types within their home ranges. Our third objective was to determine whether elk selected habitat characteristics to meet different life requisites (i.e., feeding and bedding), and whether or not elk select specific sites within the immediately available area on the basis of non-spatial and spatial attributes.

Study Area

The study was conducted in west-central Alberta along the north and south facing slopes of the Athabasca River Valley near Hinton, Alberta (53°25 N, 117°35′W). The area falls within the Lower Foothills Natural Subregion and rises in elevation from 500m to 1150m (Beckingham et al. 1996). The winter climate of the Lower Foothills Subregion is prone to warming by chinook winds (Beckingham et al. 1996). Mean monthly temperature in winter (November through February) is -7.8°C with a total annual precipitation of 60 mm (Beckingham et al. 1996). During the study (December 1994 to March 1995) the mean monthly temperature was -7.6°C, with the study area receiving 35 mm of precipitation, predominantly as snow.

Vegetation in the study area was primarily mixedwood forest, some of which were stands regenerating after clearcut logging. The area is dominated by mature mixedwood stands of Trembling Aspen (*Populus tremuloides*), Lodgepole Pine (*Pinus contorta*), White and Black Spruce (*Picea glauca* and *P. mariana* respectively), and Balsam Poplar (*Populus balsamifera*). Low-bush Cranberry (*Viburnum edule*), Prickly Rose (*Rosa acicularis*), Green Alder (*Alnus crispa*), Canada Buffalo-berry (*Shepherdia canadensis*), Marsh Reed Grass (*Calamagrostis canadensis*), and Hairy Wild Rye (*Elymus innovatus*) are common understorey species (Beckingham et al. 1996). A few large meadows also were present in the study area.

Methods

Study Animals and Site Location

From June 1993 to September 1994 elk were captured using up to eight collapsible clover traps (Thompson et al. 1989) baited with salt blocks or alfalfa. Traps were placed in areas of known elk use and checked twice daily. Captured elk were fitted with a Lotek LMRT-4 radio collar containing a mortality sensor and a head up/head down activity sensor. All animals captured were handled with care in accordance to the principles and guidelines outlined by the Canadian Council of Animal Care. Twelve animals (10 cows and 2 bulls) were tracked throughout 24-hr days during the winter of 1994/1995. Elk were located at least twice a week from 1 December 1994 to 21 March 1995, subject to field restrictions. Animals were located after 30 November 1994 to lessen the effect of hunting on habitat selection, while the 21 March 1995 date corresponded to a shift back to spring/summer range. The necessity of obtaining approximately 20 locations per animal over the winter period prohibited a complete randomized design. To reduce autocorrelation of successive locations (Swihart and Slade 1985), individual animals were located at least 72 hours apart (mean = 95.5 hours).

A Telonics TR-2 receiver with scanner and three element yagi antenna received signals from radio collared elk. Locations were taken from the ground from fixed bearing sites, with animal locations determined from 3-5 intersecting compass bearings. The interval between bearings was usually less than 25 minutes. We attempted to minimize distance between receiver and collared elk without disturbing the elk. We tried to visit each fix within 24 hours to confirm elk activity (feeding, bedding, or travelling) at that point (84% confirmed). Additional feeding and bedding sites were determined by visual sightings of non-collared elk feeding or bedded, and the discovery of feeding or bedding sites while performing radio telemetry. Only one bed or feeding site was measured per group of animals. Universal Transverse Mercator (UTM) coordinates for all locations were determined using a Trimble Global Positioning System (GPS) unit (Trimble Navigation 1992a) and differentially corrected using the software Pathfinder (Trimble Navigation 1992b).

Landscape Level Selection

Only study animals that were located ≥ 18 times during the winter were included for analysis at the landscape level (n = 9; 8 cows and 1 bull). The 95% adaptive kernal (ADK) home ranges were estimated for nine of the 12 collared elk using the program CALHOME (Kie et al. 1996). The 95% ADK UTM coordinates for the nine elk home ranges were imported into ARC/INFO (ESRI 1990) for spatial analysis. Weldwood of Canada's (Hinton Division) forest cover (Phase III data), roads, unimproved access (seismic lines, cut-lines, power lines and pipeline right-of-ways) and forest harvest data were summarized for each home range. To determine availability of habitat at the landscape level, nine random circular home ranges equal to the mean area of the nine elk home ranges were created in ARC/INFO (ESRI 1990). We termed these random circular home ranges available home ranges (AHR).

Each AHR was randomly placed but had to fall completely within the study area boundary. The forest cover, roads, unimproved access, and forest harvest data were clipped and summarized for each AHR (n for available = 9).

Stands were classified using the Phase III categories of the Alberta Forest Inventory method (Alberta Forest Service 1981) into food, thermal cover and hiding cover separately for each home range and AHR. A stand with canopy closure no greater than 50% was classified as food. Thermal cover was a stand with canopy closure of 51% or greater and a tree height of 12 m or greater. Hiding cover was defined as a stand with canopy closure of 50% or greater. These definitions were based on standard definitions for elk habitat (Thomas et al. 1979) with modifications to represent available local habitat types. A stand could be classified into more than one type under the assumption that elk utilize certain stands for more than one purpose. For example a stand could be used for both thermal and hiding cover.

For each home range and AHR, the road density, unimproved access density, patch density, and mean patch size were calculated. Road density was calculated as the kilometers of permanent roads found within an elk's home range or AHR, while unimproved access density was calculated as the kilometers of seismic lines, cut lines, power lines and gas line rights-of-way found within an elk's home range or AHR. Patch density was defined as the number of forest cover stands (≥ 1 ha) per km^2, while mean patch size was the mean size of forest cover stands. Finally the percent of each home range and AHR previously logged (between 1957 and 1985) was determined. To evaluate habitat selection at the landscape level, we compared the composition of the elk home ranges to the AHR using the Kruskal-Wallis test.

Stand Level Selection

Locations contained within the 95% ADK home range for each elk (n = 9) were classified as 1 of 10 habitat types: grass/meadow, regenerating cut, water, sapling, pole, open mature, closed mature, open old growth, closed old growth or other. Open stands had a canopy cover less than 50% while closed stands had a canopy greater than 49%. White and Garrott (1990) recommended determining habitat selection at an individual level because different animals may use the habitat differently. However, the number of relocations for each animal was inadequate for analysis at an individual level (Neu et al. 1974). Therefore, locations from each collared animal were pooled. Habitat availability was determined by averaging the percent composition of each habitat type within each elk's home range. A chi-square test was used to determine if elk used each habitat type in proportion to its availability (Neu et al. 1974). If the null hypothesis that elk were using the habitat in proportion to its availability was rejected, a Bonferroni Z statistic was calculated for each habitat type to determine if it was used more or less than expected (Neu et al. 1974).

Site Level Selection

Within a home range, specific sites are used for specific purposes. For all feeding and bedding sites, a number of vegetative and spatial variables were determined. Visual estimates (percent) of grass cover, herb cover, and shrub cover were assessed in a 0.04 ha circular plot (radius 11.3 m) centered at the site location. Also within the 0.04 ha plot the number of trees were counted and classified to determine percent spruce, pine and fir in the canopy and tree density (scaled to #/ha × 1000). Average tree height was determined by averaging the height of five trees, representing the stand, as determined using a clinometer (Bessie 1995). Canopy closure was estimated at the center of the plot using a spherical densiometer. All measurements were taken between June 1995 and September 1995, except percent canopy closure, which was measured in May.

Spatial variables were estimated from maps produced by overlaying the feeding and bedding locations with Weldwood of Canada's (Hinton Division) forest cover, road and seismic line data using ARC/INFO software (ESRI 1990). Distances to major roads, minor roads, unimproved access, forage stands, thermal cover stands and hiding cover stands were determined. All variables were estimated in meters. Major roads were defined as any hard packed road, open year round and maintained, while minor roads were defined as roads that are not maintained year round and are usually only accessible by 4×4 vehicle during the winter. Unimproved access was an inclusive term for seismic lines, cut lines, power lines and gas line right-of-ways. A 1-way ANOVA was used to determine if the mean spatial and non-spatial attributes at elk feeding sites were significantly different than those found at elk bedding sites.

To determine if elk selected particular sites for feeding and bedding, we located a paired control plot 300 m from the feeding or bedding site, in a random direction (Brown 1994). The non-spatial and spatial variables estimated at the feeding and bedding sites were also assessed at the control plots. For each non-spatial and spatial attribute, the means for the feeding and bedding sites were compared to the means at their paired control plot using a paired t-test. All tests were preformed using SPSS (Norusis 1993).

Results

Landscape Level Selection

The mean 95% ADK home range size for the nine collared elk was 23 km^2 (range: 12-53 km^2). Four landscape variables were significantly different

Table 1. Mean attributes for elk home ranges (n = 9) and available home ranges (AHR) (n = 9) for the winter of 1994–1995 in west-central Alberta.

	Elk Home Range[a]	AHR[b]	
	M + SE	Mean + SE	P Value[c]
Habitat Variables			
Food (%)	49.22 ± 1.93	48.47 ± 6.95	0.453
Thermal Cover (%)	43.28 ± 2.17	41.92 ± 6.17	0.427
Hiding Cover (%)	88.16 ± 1.28	82.21 ± 4.88	0.508
Harvested (%)	10.50 ± 3.37	7.92 ± 4.10	0.269
Density Variables			
Road Density (km/km^2)	0.32 ± 0.05	0.82 ± 0.22	0.005
Unimproved Access Density (km/km^2)	3.18 ± 0.16	2.48 ± 0.24	0.038
Patch Density(#/km^2)	42.99 ± 6.12	21.67 ± 4.85	0.012
Mean Patch Size (km^2)	0.03 ± 0.004	0.06 ± 0.009	0.007

[a] Mean home range size = 23 km^2
[b] Available home range size = 23 km^2
[c] P values are the results from Kruskal-Wallis tests.

between the elk home ranges and the AHR (Table 1). Elk home ranges had a lower mean road density, but a greater mean unimproved access density than the AHR. They also had smaller mean patch size and a greater patch density. There was no significant difference in the composition of the home ranges and AHR in terms of food and cover composition.

Stand Level Selection

For all elk home ranges combined (n = 9), the dominant cover type was closed old growth while sapling and water (i.e., lake and river) were the least prevalent cover types (Table 2). Grass/meadow accounted for 7% of the combined home ranges, while regenerating cuts accounted for 10%. The grass/meadow cover type was used more than expected, while all other habitat types were used in proportion to their availability (Table 2).

Site Level Selection

Five vegetative variables were significantly different between the 96 elk feeding and 62 bedding sites (Table 3). Compared to bedding sites, feeding sites had a lower mean percent canopy closure, percent shrub cover, tree density and tree height, but a higher mean percent grass cover. Feeding sites were significantly closer to unimproved access than bedding sites (Table 3). Although this comparison highlighted use of specific resources for specific activities, we also attempted to determine selection relative to availability.

All of the non-spatial habitat attributes were significantly different between the feeding sites and control plots, except for percent herbaceous cover (Table 4). Feeding sites had significantly less canopy closure, and less spruce, pine, and fir in the canopy than the control plots. Feeding sites had a significantly lower tree height and stem density than the control plots. Feeding sites had a greater percent grass cover and less percent shrub cover than the control plots. Only two of the five spatial variables were significantly different between elk feeding sites and the control plots (Table 4). Feeding sites were

Table 2. Habitat use at a stand level by elk (n = 9) in west-central Alberta during the winter of 1994–1995.

Habitat	Available (%)[a]	Observed (n)	Expected (n)	X^2	Bonferroni 95% Confidence Interval	Use
Grass / Meadow	7	43	13	64.94	0.137 - 0.283	More
Regenerating Cut	10	21	20	0.03	0.048 - 0.157	Equal
Water	2	0	4	3.83	0.000 - 0.000	No Use
Sapling	3	4	5	0.39	-0.005 - 0.044	Equal
Pole	10	12	20	3.22	0.016 - 0.101	Equal
Open Mature	7	18	16	0.37	0.037 - 0.139	Equal
Closed Mature	16	40	33	1.56	0.124 - 0.266	Equal
Open Old-growth	11	15	24	3.17	0.026 - 0.120	Equal
Closed Old-growth	26	39	53	3.77	0.120 - 0.126	Equal
Other	8	13	17	0.85	0.020 - 0.107	Equal

[a]Pooling all elk locations and defining the area of availability as the mean of each habitat type found within each elk's 95% ADK home range

Table 3. Mean non-spatial and spatial attributes at elk feeding (n=96) and bedding sites (n=62) in west-central Alberta during the winter of 1994–1995.

	Elk Feeding Sites	Elk Bedding Sites	
	M ± SE	Mean ± SE	P Value[c]
Non-spatial Variables			
Canopy Closure (%)	31.34 ± 3.45	64.68 ± 4.03	<0.001
Grass Cover (%)	59.73 ± 3.37	34.95 ± 3.30	<0.001
Herb Cover (%)	19.00 ± 1.16	16.85 ± 0.89	0.185
Shrub Cover (%)	15.15 ± 1.49	27.37 ± 1.76	<0.001
Spruce, Pine, & Fir in the canopy (%)	28.17 ± 4.20	38.53 ± 5.07	0.120
Stem Density (# / ha × 1000)	1.31 ± 0.19	2.03 ± 0.17	0.008
Tree Height (m)	5.57 ± 0.72	13.38 ± 0.86	<0.001
Spatial Variables			
Major Roads	1093 ± 66.06	1244 ± 87.46	0.164
Minor Roads	601 ± 70.05	763 ± 69.90	0.121
Unimproved Access	102 ± 11.30	165 ± 19.59	0.004

[a] P-values are the result of 1-way ANOVA's.

located significantly closer to unimproved access and further from hiding cover than expected on the basis of availability.

Bedding sites had a significantly higher percent grass cover, and significantly less spruce, pine and fir in the canopy than control plots (Table 5). Elk selected bedding sites with significantly fewer trees per ha than available. There was no significant difference between bedding sites and the control plots in terms of the distance to major and minor roads, and the distance to unimproved access (Table 5). There was no significant difference between the distance from the bedding site to foraging areas and the distance from the control plots to foraging areas (Table 5).

Discusion

The results from multi-scale habitat studies are largely dependent on the selection of variables chosen to investigate (Pedlar et al. 1997). Erroneous conclusions may occur if important variables are selected at one scale and frivolous variables are selected at another (Pedlar et al. 1997). Selection of variables based on the findings of previous studies may alleviate the problem of variable selection. In our study we selected variables at each scale that represented characteristics of food, thermal cover and hiding cover; requisites that have been deemed important for the selection of habitat types and features by elk. Therefore we believe reasonable variables were investigated and should provide

Table 4. Mean attributes at elk feeding (n=96) and control plots (n=96) in west-central Alberta during the winter of 1994 – 1995

	Elk Feeding Sites	Control plots	
	M ± SE	Mean ± SE	P Value[a]
Non-spatial Variables			
Canopy Closure (%)	31.34 ± 3.45	63.72 ± 3.55	< 0.001
Grass Cover (%)	59.73 ± 3.37	32.61 ± 3.20	< 0.001
Herb Cover (%)	19.00 ± 1.16	19.85 ± 1.01	0.574
Shrub Cover (%)	15.31 ± 1.50	26.25 ± 1.95	< 0.001
Spruce, Pine, & Fir in the canopy (%)	28.17 ± 4.20	44.70 ± 4.06	0.004
Stem Density (# / ha × 1000)	1.31 ± 0.19	3.24 ± 0.29	< 0.001
Tree Height (m)	5.46 ± 0.72	12.44 ± 0.78	< 0.001
Spatial Variables			
Major Road	1093 ± 66.06	1088 ± 64.50	0.829
Minor Road	601 ± 70.05	635 ± 72.24	0.139
Unimproved Access	102 ± 11.30	164 ± 12.34	< 0.001
Thermal Cover	160 ± 14.35	158 ± 18.25	0.932
Hiding Cover	71 ± 7.68	48 ± 8.06	0.024

[a] P-values are the result from paired t-test.

Table 5. Mean attributes at elk bedding (n=62) and control plots (n=62) in west-central Alberta during the winter of 1994 – 1995

	Elk Feeding Sites	Control plots	
	M ± SE	Mean ± SE	P Value[a]
Non-spatial Variables			
Canopy Closure (%)	64.68 ± 4.03	71.74 ± 4.01	0.157
Grass Cover (%)	34.95 ± 3.30	25.35 ± 2.92	0.016
Herb Cover (%)	16.85 ± 0.89	17.71 ± 1.29	0.56
Shrub Cover (%)	27.37 ± 1.76	28.26 ± 2.13	0.698
Spruce, Pine, & Fir in the canopy (%)	38.53 ± 5.07	54.21 ± 5.15	0.023
Stem Density(# / ha × 1000)	2.03 ± 0.17	3.17 ± 0.27	0.001
Tree Height (m)	13.38 ± 0.87	13.75 ± 0.78	0.701
Spatial Variables			
Major Road	1244 ± 87.46	1229 ± 84.34	0.550
Minor Road	763 ± 69.90	757 ± 72.24	0.830
Unimproved Access	165 ± 19.59	155 ± 19.50	0.684
Forage Stands	71 ± 11.14	69 ± 13.63	0.880

[a] P-values are results from paired t-test.

meaningful insight into the habitat selection patterns of elk at multiple scales.

During winter, vegetation is at its lowest quality and quantity and therefore elk should select areas containing the highest quantity of available forage. Selecting areas of high forage concentration would reduce energy expenditures associated with locomotion through snow and decreased temperatures (Geist 1982). Previous studies have shown elk prefer to graze on grasses (site selection) when snow depths do not impede foraging (Nelson and Leege 1982; Morgantini 1988). The selection of grass/meadows as foraging sites at the stand level has been well documented (Craighead et al. 1973; Morgantini and Hudson 1979; Irwin and Peek 1983; Jenkins and Wright 1986; Morgantini 1988). The proportion of a home range as forage or habitat diversity (e.g., patch size and density) may be variables that are representative of a landscape scale for elk. Previous studies have indicated habitat selection by elk at the landscape level. Irwin and Peek (1983) concluded that forage density strongly influenced the size and location of elk home ranges in Idaho. In dry shrub steppe environments, larger home ranges may compensate for low forage availability (McCorquodale et al. 1989). Black et al. (1976) proposed that optimal elk habitat consists of 40% of the land base as cover and 60% as food in the proper size and spatial arrangement. As an ecotone species, elk select heterogeneous areas for winter home ranges providing the opportunity to feed in grass meadows while taking advantage of the adjacent areas for cover (Geist 1982).

The present study confirms previous reports on selection of forage characteristics by elk at different scales. At the site scale elk selected open areas with high grass cover for feeding when compared to bedding locations and available habitat. At the stand level elk selected grass/meadows due to their concentration of grasses while utilizing all other habitat types in proportion to their availability. The results of the landscape level analysis are less conclusive. If habitat diversity, which is represented by patch size and density, is representative of a need for a heterogeneous environment to meet different life requisites, then elk did exhibit landscape level selection. Though not significant in comparison to available home ranges, elk home ranges showed little variation in the proportion classified as forage even though there was a wide range of home range sizes. This suggests that forage maybe an important factor in determining home range size and location in our study.

Closed canopies can reduce thermoregulatory costs, reduce snow depths, and provide security for elk (Peek et al. 1982; Skovlin 1982; Peek and Scott 1985). Thermal cover is provided by stands that protect against extreme temperatures, whereas hiding cover provides a sense of security from predators and human disturbance. Much debate has centered around whether elk select closed stands for their thermal or hiding cover value (Geist 1982; Cook et al. 1998). Beall (1976) concluded that elk selected closed stands to reduce heat loss, whereas Peek and Scott (1985) believed that thermal cover would have an insignificant effect on energy requirements. They concluded that security cover was important in the presence of human disturbance (Peek and Scott 1985). In western Alberta, Morgantini and Hudson (1979) concluded that habitat selection by elk in winter was not a response to the thermal environment, but governed by human disturbance.

Our results suggest that elk did not select for thermal cover requirements at any scale. At the landscape level the proportion of the home range classified as thermal cover was comparable to that of the

AHR, while at the stand level those habitat types that would represent thermal cover (e.g., closed mature or closed old-growth) were used in proportion to their availability. At the site scale elk selected bedding sites whose structural characteristics would be considered of lower thermal cover quality than the available habitat.

The need for hiding cover by elk is well documented (Hershey and Leege 1976; Morgantini and Hudson 1979; Peek and Scott 1985). Most studies have described the need for hiding cover in regards to human disturbance and, in particular, roads. The avoidance of habitat near open roads by elk has been extensively documented (Hershey and Leege 1976; Lyon 1979; Rost and Bailey 1979). Most studies have established avoidances of roads in terms of a distance, but Lyon (1983) determined avoidance or loss of habitat in terms of road density. Habitat effectiveness decreases dramatically as the density of roads increases such that an area with a road density greater than 0.62 km/km^2 is reduced by 40% (Lyon 1983).

The results of selection by elk at multiple scales in terms of security requirements are less conclusive than those found for forage and thermal cover requirements. At the landscape level there was not a significant difference in the proportion of hiding cover comprising either the elk home ranges or AHR. This is not surprising as the study occurred in an area that is predominantly forested. We would argue that selection at the landscape level did occur in terms of hiding cover requirements based on the results of the road density analysis. Road densities for the elk home ranges were significantly less than those of the AHR. In addition the densities are below the 0.62 km/km^2 density established by Lyon (1983).

Previous studies of habitat selection have been conducted at a single scale, with results being extrapolated to higher or lower levels (Pedlar et al. 1997). The appropriateness of extrapolating results to other levels has not been examined. Our results involving selection by elk of forage characteristics at the three levels would support the extrapolation of results to higher or lower levels. Based on our analysis, conclusive results for habitat selection were observed at the site and stand scale with inconclusive results at the landscape scale. This suggests that habitat selection, in terms of forage requirements, are bottom up as opposed to top down. There was no selection detected at any level by elk to meet the needs of the life requisite of thermal cover, therefore extrapolation to other levels would be appropriate (though unnecessary). The appropriateness of extrapolating the results of the hiding cover analysis is less conclusive. Selection of habitat characteristics to meet the requirement of hiding cover was not evident at the stand or site level, but may have been masked by the selection at the landscape level. During different times of the year and under increased levels of human disturbance selection for hiding cover may be more evident at the stand and site level.

We acknowledge that our conclusions are based on the analysis of habitat selection data from one winter with lower than average precipitation levels. Because of this we did not examine the influence that snow depth had on habitat selection. It was also beyond the scope of our study to examine other factors (e.g., predation, inter and intra-specific competition) that can influence habitat selection. To overcome these limitations, further investigation is warranted to determine how these other factors change habitat selection patterns and our conclusions. The value of our study is to show resource managers the need to examine habitat selection patterns across more than one level to better manage elk.

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Notable Vascular Plants from Alaska in Wrangell-St. Elias National Park and Preserve with Comments on the Floristics

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Cook, Mary B., and Carl A. Roland. 2002. Notable vascular palnts from Alaska in Wrangell-St. Elias National Park and Preserve with comments on the floristics. Canadian Field-Naturalist 116(2): 192–304.

An inventory of the vascular flora north of the Bagley Icefield in Wrangell-St. Elias National Park and Preserve, Alaska, U.S.A., was conducted from 1994 to 1997. The objectives of the inventory were to assess the genetic diversity of the region, identify rare taxa and areas of phytogeographic interest and to assist park managers with planning and environmental compliance. The purpose of this paper is to present annotations for 212 of the most notable taxa with their Alaska-Yukon and Park distribution maps and to summarize the floristics of the Park. 832 species (887 taxa) were documented as occurring within the Park (approximately 54% of the Alaskan flora). Significant results from the inventory include: (1) nine additions to the flora of Alaska (*Arabis calderi* G. A. Mulligan, *A. codyi* G. A. Mulligan, *A. drepanoloba* Greene, *A. lemmonii* S. Wats., *Carex petasata* Dewey, *Draba lonchocarpa* Rydb. var. *thompsonii* (C. L. Hitchc.) Rollins, *Festuca minutiflora* Rydb., *Najas flexilis* (Willdenow) Rostkov. & Schmidt and *Trichophorum pumilum* (Vahl.) Schinz & Thell. var. *rollandii* (Fern.) Hultèn); (2) 331 range extensions; (3) the addition of 40 Alaska Natural Heritage plant taxa with a state rank of three or less for a total of 69 rare plant taxa in the Park's flora, and (4) the addition of 214 species to the Park's flora. The composition of the flora in percentages, with the rare flora in parenthesis, is: 25.8 (8.3) circumpolar, 10.8 (9.7) incompletely circumpolar, 32.2 (38.9) North American, 23.2 (11.1) amphiberingian, 0.9 (1.4) amphiatlantic and 7.1 (26.4) Alaska-Yukon endemic. The Alaska-Yukon and amphiberingian endemic elements are dominant in the Alaska Range, the Wrangell Mountains and in the Tanana, White and Copper River basins whereas the Cordilleran endemic element is dominant in the St. Elias and Chugach Mountains and Chitina River basin. These trends correspond to our understanding of plant migration after the Pleistocene Epoch from refugia in the Upper Yukon Valley, the Alaska Range and Beringia, the northern part of the Park being closest to these migration corridors, whereas the St. Elias and Chugach Mountains are at the northern end of the North American cordilleran migration corridor. Endemics may also have evolved from relict populations in unglaciated areas within the Late Wisconsin ice sheet adjacent to Lake Ahtna, on coastal refugia and on exposed sites in the dry northern interior of the Park bordering the Tanana Valley and the southeastern edge of Beringia. The rare flora was distributed somewhat evenly through the mountain ranges of the Park, but unevenly throughout the basin regions of the Park where the Chitina River basin had two to four times the number of rare species found in the other basins. There was a trend for rare plants to occur in the alpine zone, above 1200 m elevation, in xeric sites, in the alpine-herb talus slope plant community, on southerly aspects and on slopes of 20–40 degrees. Although the Park is protected, infrastructure development, visitor use in the backcountry in communities most likely to harbor rare plants, and global changes to the ecosystems are increasing. This inventory enhanced our understanding of the genetic diversity, phytogeography and distribution of our flora, however, there are still large areas in the Park that have not been surveyed, particularly in the coastal region, and we lack sufficient knowledge about most rare species (distribution, life history and population ecology) to develop protection plans.

Key Words: Vascular plants, flora, rare plants, floristics, biogeography, range extensions, National Park, Alaska.

Wrangell-St. Elias National Park and Preserve encompasses a unique cross section of boreal and coastal ecosystems in south-central Alaska with floristic influences from Beringia, the Yukon, the arctic and the Pacific Mountain systems (Figure 1). There is a high diversity of plant communities in this region due in part to the large size of the Park (5.3 million hectares), the three climatic zones it covers (interior, montane and transitional) and the wide variety of landforms and lithologies found within its boundaries.

Eric Hultèn, in his history of botanical exploration in Alaska, identified the Wrangell-St. Elias region as one of three areas in Alaska that was poorly known (Hultèn 1940). The distribution maps in his flora of Alaska (Hultèn 1968) show a void in the Wrangell-St. Elias region for many boreal-montane and arctic-alpine taxa that would be expected to occur here. Published floristic studies within the Park were limited to a few geographic areas: Skolai Creek, Chitistone Pass and the Chitistone River (Murray 1968, 1971); Russell, Sheep and Guerin Glaciers (Murray 1971); Chitistone, Skolai and Frederika Valleys (Scott 1968, 1974); Long Glacier and Dadina River (Saltmarch 1978) and Bonanza Ridge near Kennicott (Nordell and Schmitt 1977). Other collections were made prior to the establishment of the Park, but these were primarily along the two roads into the Park. Collections made from 1984 to 1992 during Park vegetation studies documented 121 range extensions, twenty-two new rare plant species and verified that large areas of the Park were still unsurveyed.

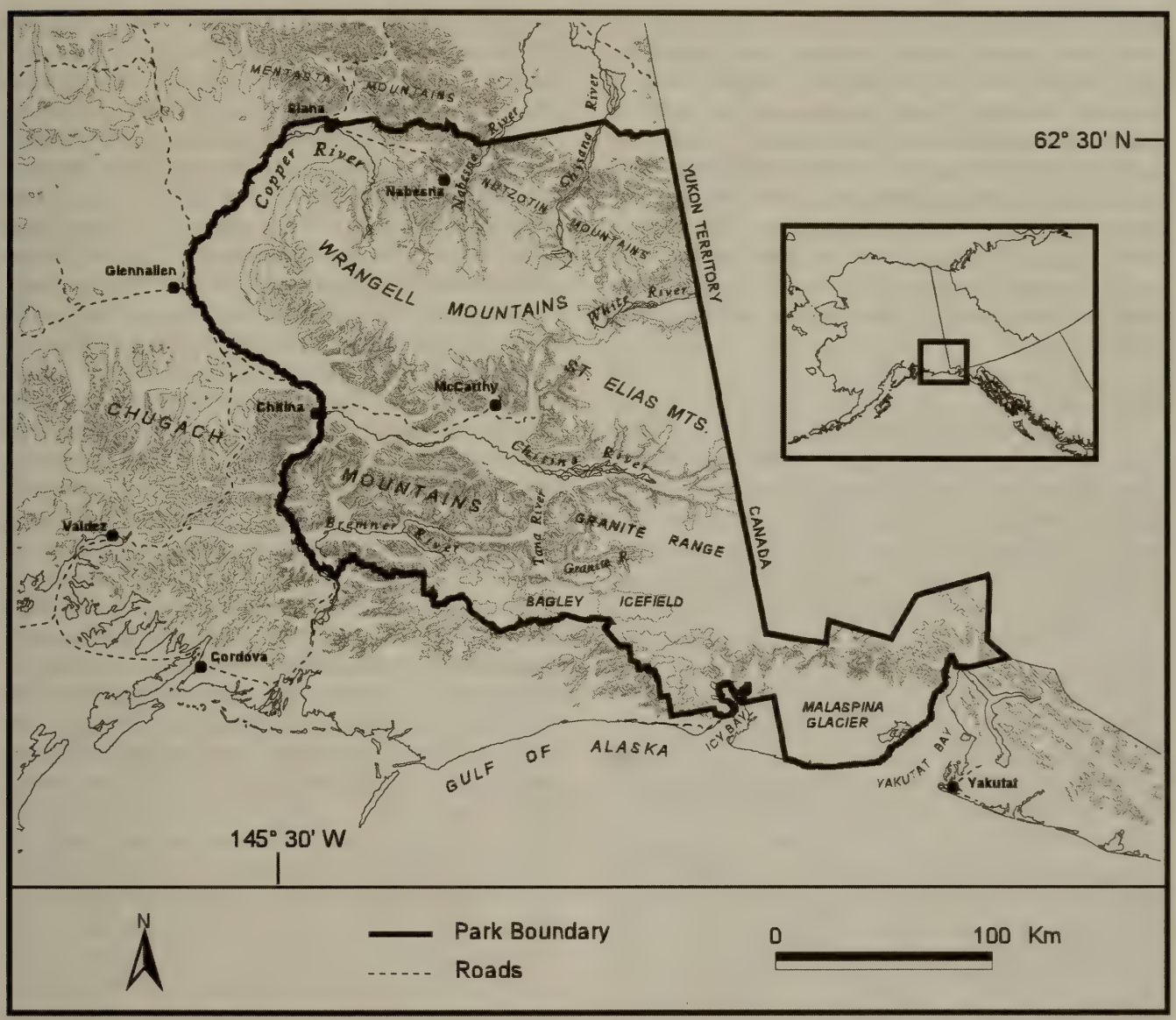


FIGURE 1. Map of study area showing major geographical features of Wrangell-St. Elias National Park and Preserve, Alaska.

The Park was established in 1980 under the Alaska National Interest Lands Conservation Act (ANILCA, Public Law 96-487). An inventory of the plants occurring within the Park is necessary to fulfill the following management objectives of the Park as stated in the Final Environmental Statement (Alaska Planning Group 1973):

1. Ensure retention of the magnificent Wrangell-St. Elias landscapes and living systems in a natural state.
2. To the extent possible, allow the natural fluctuations and equilibrium of self-regulating ecosystems to continue unimpeded.
3. Develop and implement a viable research program to provide basic information required for effective Park management.
4. Lay early emphasis on identification of especially fragile areas through appropriate research.

The Natural Resources Management Guideline for the National Park Service, NPS-77 (USDI 1991) states that, "A basic vegetation inventory is the first step in vegetation management", and the General Management Plan for the Park mandates that the presence and extent of endangered species of flora and fauna be determined (USDI 1986). Vegetation in the Park is subject to alteration from recreational and subsistence uses including mining, timber harvest, grazing, all-terrain vehicles, hiking, climbing and camping. Backcountry use is increasing steadily as the Park infrastructure is developed and as the public seeks to experience new premier wilderness areas. Identification of sensitive taxa, their habitats, and unique floristic associations was deemed necessary by the National Park Service for the preparation of backcountry management plans, environmental assessment and compliance and for the monitoring of subsistence uses.

We conducted an inventory of the vascular flora of selected areas north of the Bagley Icefield within the Park from 1994 to 1997. The objectives of the

inventory were to: increase our understanding of the ecological history, genetic diversity and biogeography of the Park's flora; identify populations of rare taxa, unique floristic associations and areas of phytogeographic interest in order to protect the biodiversity of the natural systems within the Park, and to provide the structure for an ongoing assessment of the Park's flora. The purpose of this paper is to present the collection data for the most notable range extensions along with Park and Alaska-Yukon distribution maps and to summarize the floristics of the Park.

Study Area

Four large mountainous regions define the landscape of the Park: the Wrangell Mountains, the St. Elias Mountains, the Chugach Mountains and the Alaska Range. The Wrangell Mountains, a volcanic range with peaks reaching 4995 m, dominate the landscape in the center of the Park. The most common bedrock in the Wrangell Mountains is Wrangell Lava, although the southern Wrangells have large exposures of Chitistone and Nizina limestone, Nikolai Greenstone and metamorphosed sedimentary rocks (MacKevett 1978; Richter 1976). The St. Elias Mountains straddle the border with the Yukon Territory and are even more precipitous and heavily glaciated than the Wrangell Mountains with peaks rising to 5489 m. The most common surface rock types in the St. Elias Mountains are Wrangell lava, Nikolai greenstone and marine sedimentary rocks of the Hasen Creek formation such as argillite, chert, conglomerate, limestone and shale (MacKevett 1978). The Chugach Mountains are heavily glaciated due to their proximity to the Gulf of Alaska and extensive glaciation during the Pleistocene as indicated by the steep-sided U-shaped valleys, obvious trimlines, hanging glaciers and sparsely vegetated morainal features. The lithology of the Chugach Mountains is dominated by rocks of the Valdez group, a marine sedimentary unit composed primarily of graywacke, argillite, slate and phyllite (MacKevett 1978). North of the Wrangell Mountains lies the eastern arc of the Alaska Range which lies south of the Denali Fault and is represented within the Park by the Mentasta and Nutzotin Mountains. The lithology of the eastern Alaska Range is largely composed of marine sedimentary rocks with exposures of Nikolai Greenstone and thin-bedded limestone (Richter 1976).

The Copper, Chitina, White and Tanana (including the Nabesna and Chisana Rivers) are major interior river drainage systems found within the Park. These drainage basins are mantled with quaternary surficial deposits of diverse origins. Surficial deposits include drift from the Wisconsin and older glaciations, Eolian deposits, Holocene alluvium and lacustrine sediments. The principal depositional feature in the Copper River basin was the presence of the huge pro-glacial Lake Ahtna, which formed behind an ice dam at the confluence of the Copper and Chitina Rivers during the Pleistocene Epoch. Lake Ahtna occupied more than 520 000 hectares of the Copper River basin to a maximum elevation of 800 m on the flanks of the Wrangell Mountains (Ferrians 1989). In contrast to the large expanses of open, low elevation terrain present in the Copper River basin, the upper Nabesna and Chisana Rivers occupy relatively narrow valleys. The valley floors of these braided rivers lie within the active floodplain of the streams. The surficial deposits in the large, open valleys of the Chitina and White Rivers are a mix of alluvium on the floodplains and glacial outwash and drift from the Wisconsin glaciation on surfaces that have not been reworked by fluvial processes. Large areas in the White River valley are blanketed with volcanic ash from the eruptions of Mt. Churchill that occurred 1900 and 1250 years ago.

Precipitation in the Park ranges from a yearly average of 338 cm at Yakutat, located in the maritime climatic zone, to 20 cm at Slana in the interior climatic zone. Temperatures on the coast are mild ranging from a mean daily high of 15°C to a mean daily low of –9°C whereas temperatures at Slana range from a mean daily high of 20°C to a mean daily low of –25°C.

Five ecoregions and three transitional areas are found within the Park (Gallant et. al. 1995). These are: (1) the coastal Western Hemlock-Sitka Spruce forest ecoregion which is found on the Malaspina Forelands between Icy and Yakutat Bays; (2) the Pacific Coastal mountain ecoregion which includes the Chugach Mountains, southern St.-Elias Mountains and the Bagley Icefield; (3) the Wrangell Mountain ecoregion, demarcated by the Wrangellia Terrane; (4) the Copper Plateau ecoregion, the area of pro-glacial Lake Ahtna; (5) the Interior Highlands ecoregion, delineated by the Yukon-Tanana Terrane in the northeast corner of the Park; (6) the Alaska Range transition ecoregion encompassing the Nutzotin and Mentasta Mountains; (7) the interior bottomlands transition ecoregion, the region north of the Nutzotin Mountains in the Tanana Lowlands, and (8) the Duke Depression transitional ecoregion, the area encompassing the White River along the Duke River fault.

Most of the Park was covered by the Cordilleran ice sheet or by the large pro-glacial Lake Ahtna during the peak of the Wisconsin glaciation (Clague 1992; Hamilton 1994; Hamilton and Thorson 1983). The major river valleys became ice-free and Lake Ahtna drained with the retreat of the glacier occupying the mouth of the Copper River canyon by 9.4 ka (Denton 1974; Hamilton 1994). There may have been unglaciated areas within the Late Wisconsin ice sheet adjacent to Lake Ahtna (Hamilton and Thorson 1983), on coastal refugia and on exposed sites in the

dry northern interior of the Park bordering the Tanana Valley and the southeastern edge of Beringia (Hopkins 1967).

Previous Botanical Collections

Eight significant plant collections were made within the Park prior to its establishment in 1980. William L. Poto collected 175 specimens primarily along the Mt. Drum Trail in the central Wrangell Mountains in 1902 as a member of the United States Geological Survey (USGS) Mt. Wrangell and Central Copper River Region Exploration Expedition (Poto 1902*; Mendenhall and Schrader 1903; Mendenhall 1905; Hultén 1940). Frank Charles Schrader and G. H. Hartman collected in the northern Wrangell Mountains between the Nabesna and Copper Rivers the same year as Poto as part of this expedition. The specimens of Poto, Schrader and Hartman are at the U.S. National Herbarium. David W. Eaton, DeLorme D. Cairnes and H. F. Lambart collected along the Yukon border, in the Park in the Wrangell and St. Elias Mountains from 1909–1913 as part of the Yukon-Alaska International Boundary Survey (Cairnes 1911, 1914; Macoun 1914; Hultén 1941–1950; Green 1982). The collections of Eaton are at the U.S. National Herbarium, those of Cairnes and Lambart are at Canadian Museum of Nature in Ottawa. Hamilton M. Laing, a biologist with the Department of Mines of British Columbia who was a member of the Mt. Logan expedition in 1925, collected 243 specimens at the head of the Chitina River primarily in the St. Elias and Chugach Ranges. His collection was classified by A. E. Porsild and is housed at the Canadian Museum of Nature in Ottawa (Porsild 1939; Lambart 1926a, 1926b; Hultén 1941–1950).

David F. and Barbara Murray collected at May Creek, Nizina, Chitistone Pass, Skolai Pass, Guerin Glacier, Russell Glacier and Sheep Glacier in the Wrangell-St. Elias Mountains from 1966 to 1981 (Murray 1968, 1971). Their collections are at the University of Alaska Fairbanks Museum and at the Canadian Museum of Nature in Ottawa. Richard W. Scott collected at Frederika Glacier, Chitistone Pass and Snag Glacier in the Wrangell Mountains in 1967 and 1968 while conducting an ecological phytogeographical study of the southeastern Wrangell Mountain flora (Scott 1968, 1974). Scott's collection is at the University of Alaska Fairbanks Museum and at the University of Michigan. Olle Nordell and Alf Schmitt collected 207 specimens at Kennicott and Bonanza Ridge in the Wrangell Mountains in 1976 (Nordell and Schmitt 1977). Their specimens are at Lund and the University of Alaska Fairbanks Museum. Ransom Saltmarch collected 76 specimens in 1978 on the slopes of Mt. Wrangell while conducting research for a novel (Saltmarch 1978). His specimens were reviewed by D. F. Murray (ALA).

An additional 36 individuals collected primarily along the two roads into the Park or on the roads adjacent to the Park. Among these collectors are: Edwin F. Glenn (1899), Martin Woodlock Gorman (1898 and 1899), E. L. Blaschke (1820), Arthur James Collier (1902), Adolphus Washington (1905), I. E. Diehl (1908), Walter Harrison Evans (1909), Bayne-Beauchamp Expedition (1932), William Albert Setchell (1932), Frits Warmolt Went (1934), Jacob Peter Anderson (1935 and 1944), Elisabeth Kol (1936), H. M. Raup (1944), Artheme-Antoine Dutilly and Ernest LePage (1945–1947), Eric Hultén (1961), M. Sharrock (1962), George Argus (1967), R. Pegau (1968, 1970), and Leslie Viereck (1957–1980). The only collections made along the Park's coast were eight made by Frederick Funston in 1892 near Esker Stream and Manby Point on the Malaspina Forelands, five made by the Harriman Expedition at the Hubbard Glacier in 1899 and numerous *Salix* specimens collected by George Argus near Esker Stream (Coville and Funston 1896; Hultén 1941–1950; Argus 1967). Park staff collected 1145 specimens at 215 unique localities throughout the Park from 1982 to 1994 during research and resource management studies.

Methods

We conducted a reconnaissance inventory north of the Bagley Icefield from 1994–1997. Site selection focused on surveying a range of plant communities, lithologies (such as calcareous, ultramafic, basalt, ash and greenstone) and landforms (such as south-facing bluffs, sand dunes, warm springs and floodplains). We also focused site selection on azonal communities (scree slopes, wetlands and aquatics) and those areas where we predicted rare and endemic species would occur. In all, 239 sites were surveyed and approximately 7000 specimens were collected.

Specimens were critically examined by the authors, Alan Battan, David F. Murray and Carolyn Parker at the University of Alaska Museum and the following specialists: George W. Argus (CAN) — *Salix*; Reidar Elven (O) — *Draba lactea* and *Cerastium regelii;* Mark Egger (WTU) — *Castilleja;* Barbara Ertter (UCB) — *Potentilla diversifolia* and *P. drummondii*; Donald Farrar (ISC) — *Botrychium;* Signe Frederickson (C) — *Festuca*; G. A. Mulligan (DAO) — *Arabis* and *Draba*; David F. Murray — *Papaver* and *Carex* section Atratae; and Marcia Waterway (MTMG) — *Carex laxa.*

We developed a set of relational databases in which the biogeography, taxonomy and rarity of each species was recorded and site characteristics for each rare plant collection was documented and evaluated. Distribution maps were prepared for selected taxa by assembling the following locality

*See Documents Cited section.

data into a Geographic Information System: all collections from this inventory and previous Park collections, specimen records from the University of Alaska Fairbanks Museum Plant Documentation Center and published stations from regional floras and monographs (Aiken and Darbyshire 1990; Argus 1973; Argus 2000; Bayer 1993; Cody 1996; Cody et. al. 1998; Hultén 1941–1950; Hultén 1968; Porsild and Cody 1980). The distribution maps are at two scales, one encompassing all of Alaska and the Yukon Territory including adjacent parts of Canada and one focused on the Park. Nomenclature follows Cody (1996) for scientific names and Kartesz and Meacham (1999*) for common names.

Results and Discussion

Taxonomic Composition

There are 832 species documented by vouchers within the Park, with a total of 887 taxa including intraspecific taxa. The flora of the Yukon Territory has approximately 1199 species, the flora of Alaska has approximately 1535 species and the two regions combined have approximately 1654 species with 1202 species in common (Kartesz and Meacham 1999). The number of species in the Park's flora is therefore approximately 54% of the Alaskan flora and 69% of the Yukon Territory flora. For comparison with other protected areas, Denali National Park and Preserve in Alaska reported 684 taxa in 2000 and Kluane National Park in the Yukon Territory has recorded 704 taxa (656 species) (Caswell 2002*).

The flora of the Park is distributed among 81 families and 258 genera. Eight of the species are not native to Alaska. The most important plant families within the flora are the Cyperaceae with 100 species (104 taxa), the Poaceae with 69 species (84 taxa), the Asteraceae with 68 species (75 taxa) and the Brassicaceae with 66 species (71 taxa).

Phytogeography

The Wrangell-St. Elias region is located within the distribution patterns of the major North American floristic elements, hence the plant species here have diverse origins and histories. They include species endemic to the area, broadly distributed boreal forest plants, arctic-alpine species, endemics of the western mountains and amphiberingian taxa of Asian origin. We recognize the following floristic elements within the vascular flora of the Park:

I. *Circumpolar species* — 25.8% of the flora (226 species). This group includes those broadly distributed species that occur on all circumpolar continents including both Asiatic and European regions of Eurasia, Greenland and North America. We further divide this group of plants into boreal species primarily found in lowland and montane habitats and arctic/alpine taxa that generally occur in treeless landscapes in the arctic or alpine regions. A third element of the circumpolar flora is a group of more wide-ranging species with broad ecological amplitudes that occur across both arctic and boreal zones. The ratio of these elements within the circumpolar flora and examples of taxa from each category are:

(1) Arctic-alpine species (10.6%) — *Cardamine bellidifolia, Carex lachenallii, Draba fladnizensis, Erigeron humilis, Saxifraga oppositifolia* and *Silene acaulis.*
(2) Boreal-montane species (6.7%) — *Carex tenuifolia, Linnaea borealis* and *Rosa acicularis.*
(3) Widespread species (8.5%) — *Carex capillaris, Empetrum nigrum, Equisetum arvense* and *Poa glauca.*

II. *Incompletely circumpolar species* — 10.8% of the flora (94 species). Species in this group have distributions that are very similar to the circumpolar plants of boreal distribution, but are not known from either Greenland or Europe. Examples of incompletely circumpolar species include *Calypso bulbosa, Carex limosa, Chamaedaphne calyculata, Equisetum fluviatile,* and *Moehringia lateriflora.*

III. *North American species* — 32.2% of the flora (282 species). Taxa in this group have distributions that are generally restricted to North America. Two additional groups of species with more narrow distributions can be identified within the North American element: cordilleran species, which occur in the western mountains, and Pacific coastal species, which are generally restricted to the coast ranges and the west coast of North America.

(1) Arctic-alpine species (2.1%) — *Erigeron compositus* and *Primula egaliksensis*
(2) Boreal-montane species (11.4%) — *Shepherdia canadensis* and *Viburnum edule*
(3) Cordilleran species (10.2%) — *Luetkea pectinata* and *Salix commutata*
(4) Pacific coastal species (6.2%) — *Lupinus nootkatensis* and *Epilobium luteum*
(5) Widespread species (2.4%) — *Solidago multiradiata*

IV. *Amphiberingian species* — 23.2% of the flora (203 species). These are species that occur in North America and northern Asia but are not known from either Greenland or Europe; hence their center of distribution generally lies within Beringia. We separate the species within the amphiberingian biogeographic element into the following categories:

(1) Arctic-alpine species (8.9%) — *Artemisia arctica* and *Senecio atropurpureus*
(2) Boreal-montane species (4.3%) — *Achillea sibirica* and *Boschniakia rossica*
(3) Pacific coastal species (5.0%) — *Carex macrocheata* and *Fritillaria camschatcensis*
(4) Widespread species (5.0%) — *Parrya nudicaulis* and *Carex podocarpa*

V. *Amphiatlantic species* — 0.9% of the flora (8 species). Taxa in this group of species have distributions that include North America, Greenland and Europe but are not known from Asia. *Carex nardina* and *Draba crassifolia* are examples of this element.

VI. *Alaska-Yukon endemic species* — 7.1% of the flora (62 species). These are species that are restricted to Alaska and Yukon Territory, and sometimes extend into neighboring regions of Northwest Territiories and British Columbia.

(1) Arctic-alpine species (2.3%) — *Thlaspi arcticum* and *Smelowskia borealis*
(2) Boreal-montane species (2.2%) — *Salix setchelliana* and *Artemisia alaskana*
(3) Cordilleran species (1.4%) — *Synthyris borealis* and *Stellaria alaskana*

(4) Pacific coastal species (1.3%) — *Castilleja unalaschensis* and *Salix stolonifera*

The composition of our flora is very similar to that described by George Douglas for the southwest Yukon (Douglas 1974). The northerly elements (circumpolar, incompletely circumpolar, North American arctic-alpine, amphiatlantic and amphiberingian) comprise 64% of both floras whereas the southern elements (Cordilleran and Pacific Coast) contribute 16% to each flora. The North American boreal-montane group contributes 14% to the southwest Yukon flora and 11% to the Wrangell-St. Elias flora. The southwest Yukon flora had eight nonnative species in 1974 as does the current Wrangell-St. Elias flora. Alaska-Yukon endemics comprise 7% of our flora and 5% (32 species) of the southwest Yukon flora reported by Douglas (1974). Lausi and Nimis (1985) documented 23 Alaska-Yukon endemics for the southern Yukon in a phytosociological study along the Alaska Highway. Porsild (1951) estimated that amphiberingian species comprise approximately 33% of the Alaska-Yukon flora. Douglas noted the southward decrease in this element for the southwest Yukon flora (17%). The slight increase in the contribution of this element to the Wrangell-St. Elias flora (23%) would support this gradient.

We found the ratio of arctic and coastal elements of the southern Wrangell Mountain flora to be similar to that described by R. W. Scott in his phytogeographical study of the southeast Wrangell Mountains (Scott 1974). Scott's analysis described a total of 291 species with 21% arctic, 7% coastal, 55% montane and 17% boreal. Our analysis resulted in 334 species for the southern Wrangells with 39% arctic-alpine, 23% boreal-montane, 12% cordilleran, 6% Pacific coastal, 20% widespread and 0.3% introduced.

Distribution of the Endemic Elements within the Park

We evaluated the ratio of the endemic elements (Alaska-Yukon, amphiberingian, cordilleran and Pacific coastal) within each of the mountain and basin regions in the Park to determine if the compositional patterns are related to the ecological history of the region (Figures 2 and 3). The Alaska-Yukon and amphiberingian endemic floras are dominant in the Alaska Range (39% and 40% respectively), the Wrangell Mountains (28% and 42%) and in the Tanana (58% and 18%), White (39% and 52%) and Copper River basins (43% and 35%). This trend corresponds to our understanding of plant migration after the Pleistocene Epoch from refugia in the Upper Yukon Valley, the Alaska Range and Beringia, the northern part of the Park being closest to these migration corridors (Hultén 1937; Murray, et. al. 1983; Yurtsev 1963; Murray 1995). The Cordilleran endemic flora is dominant in the St. Elias Mountains (45%), Chugach Mountains (37%) and in the Chitina River basin (38%) as would be expected since the St. Elias and Chugach Mountains are at the northern end of the North American cordilleran. Several of our rarest species are cordilleran endemics reaching their northern extent in the Park (*Arabis calderi* G. A. Mulligan, *A. lemmonii* S. Wats, *Carex petasata* Dewey, and *Festuca minutiflora* Rydb). The Pacific coastal endemic element decreases notably from south to north in both the mountain and basin ranges. This trend may indiciate that migration north from the coast is impeded by the mountain ranges or by the availability of suitable habitat. The strong latitudinal gradient may also indicate that the Pacific coastal species represent a younger element in our flora when compared to the other three elements, which are more evenly distributed throughout the basin and

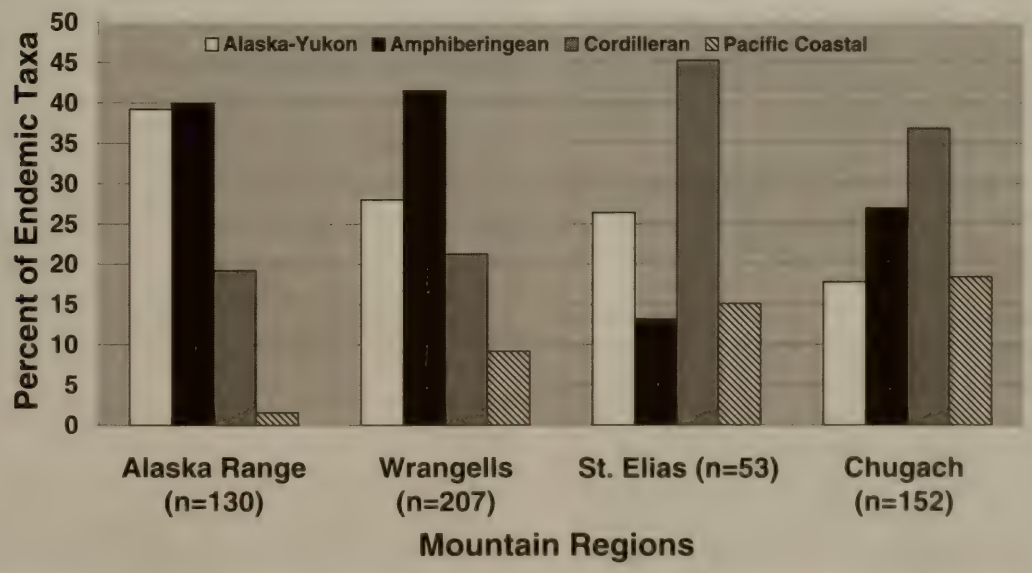


FIGURE 2. Ratio of endemic taxa within mountain regions of Wrangell-St. Elias National Park and Preserve, Alaska.

mountain ranges. Endemics may also have evolved from relict populations in unglaciated areas within the Late Wisconsin ice sheet adjacent to Lake Ahtna (Hamilton and Thorson 1983), on coastal refugia and on exposed sites in the dry northern interior of the Park bordering the Tanana Valley and the southeastern edge of Beringia (Hopkins 1967).

The Rare Flora

Sixty-nine species in the Park's flora have an Alaska Natural Heritage state rank less than three and are treated as rare species by the National Park Service, 40 of these are new to the Park's flora. None of the rare species are considered threatened or endangered by the U.S. Fish and Wildlife Service. However, three species were listed as Species of Concern by the U.S. Fish and Wildlife Service in 1995 (*Cryptantha shackletteana* L.C. Higgins, *Carex laxa* Wahlenb. and *Taraxacum carneocoloratum* Nels.).

The most important families in the rare flora are the Brassicaceae with 17 species, the Cyperaceae with 13 species and the Caryophyllaceae with seven species. The three dominant classes for the distribution of our rare flora by form of rarity (Rabinowitz 1981) are: constantly sparse and geographically restricted in a specific habitat (30 species), locally abundant in a specific habitat but restricted geographically (17 species) or constantly sparse in a specific habitat but occurring over a large range (12 species).

Trends in the distribution of the rare flora by site characteristics are summarized by the following values. The number in parenthesis is the percent of total sites with that particular value for a site characteristic evaluated using 239 sites and 423 rare plant collections. 82% (37%) of all rare plant collections were made in the alpine zone; 78.5% (41.8%) were above 1200 m; 61% (37%) were in a xeric moisture class, and 57% (19%) were on alpine herb-talus slopes. 57% of all plant collections had a slope of 20–40 degrees and 45% were collected on southerly aspects. The remaining aspect classes were distributed approximately equally (north — 17%, east — 19% and west — 19%).

The rare flora appears to be distributed relatively evenly throughout the mountain ranges (>1067 m) in the Park. The Alaska Range has 32 rare species, six of these being unique to the Alaska Range; the Wrangell Mountains have 33 species with three species unique to the Wrangell Mountains; the St. Elias Range has 19 rare species, two of which are unique to the St. Elias Range; and the Chugach Mountains (including the Granite Range) have 28 rare species, eight of which are unique to the Chugach Mountains. The distribution of rare plants is uneven for the river basins in the Park. The Chitina River Basin has 32 rare species, six of which are unique to this basin. The Tanana River has 13 rare species, two being unique; the Copper River basin has 13 rare species, two being unique, and the White River basin has eight rare species, with no species unique to that basin.

The biogeographic composition of the rare flora with examples of species from each element follow.

I. *North American species* — 38.9% (28 species).
   (1) Arctic-alpine (1 species) — *Primula egaliksensis*
   (2) Boreal-montane (8 species) — *Agoseris glauca, Carex parryana, Eriophorum viridi-carinatum* and *Maianthemum stellatum*
   (3) Cordilleran (19 species) — *Arabis calderi, A. lemmonii, Carex petasata* and *Festuca minutiflora*

II. *Alaska-Yukon endemics* — 26.4% (19 species).
   (1) Arctic-alpine (6 species) — *Thlaspi arcticum* and *Douglasia arctica*
   (2) Boreal-montane (3 species) — *Cryptantha shackletteana, Lupinus kuschei* and *Salix setchelliana*
   (3) Cordilleran (6 species) — *Arabis codyi* and *Taraxacum carneocoloratum*

III. *Amphiberingean species* — 11.1% (8 species)
   (1) Arctic-alpine (5 species) — *Festuca lenensis, Stellaria umbellata* and *Trisetum sibiricum*
   (2) Boreal-montane (1 species) — *Potamogeton subsibiricus*
   (3) Pacific coastal (2 species) — *Rumex beringensis* and *Salix hookeriana*

IV. *Incompletely circumpolar* — 9.7% (7 species)
   (1) Arctic-alpine (1 species) — *Cryptogramma stelleri*
   (2) Boreal-montane (4 species) — *Tricophorum pumilum* and *Carex laxa*
   (3) Widespread (2) — *Ceratophyllum demersum* and *Myriophyllum verticillatum*

V. *Circumpolar* — 8.3% (6 species)
   (1) Arctic-alpine (5 species) — *Colpodium vahlianum* and *Cerastium regelii*
   (2) Boreal-montane (1 species) — *Viola selkerkii*

VII. *Amphiatlantic* — 1.4% (1 species) — *Najas flexilis*

The main differences between the biogeography of the total flora and the rare flora are the increase in the ratio of Alaska-Yukon endemics in the rare flora which is only 7% of the total flora, and the decrease in the ratio of circumpolar and amphiberingian elements in the rare flora which is 37% and 24% of the total flora respectively. The ecological distribution of the rare flora is: cordilleran (38%), boreal-montane (25%), arctic-alpine (24%), Pacific coastal (6%), temperate disjunct (6%) and widespread (3%). The primary differences in the ecological distribution of the rare flora as compared to the total flora are the increase in the cordilleran element in the rare flora, which is only 12% of the total flora and the decreases in the Pacific coastal and widespread elements in the rare flora which is 12% and 20% of the total flora respectively.

Recommendations

This inventory has enhanced our understanding of the biodiversity and phytogeography of the region and has filled in the 'Wrangell Void' for many species not known to occur in the Park or thought to be rare.

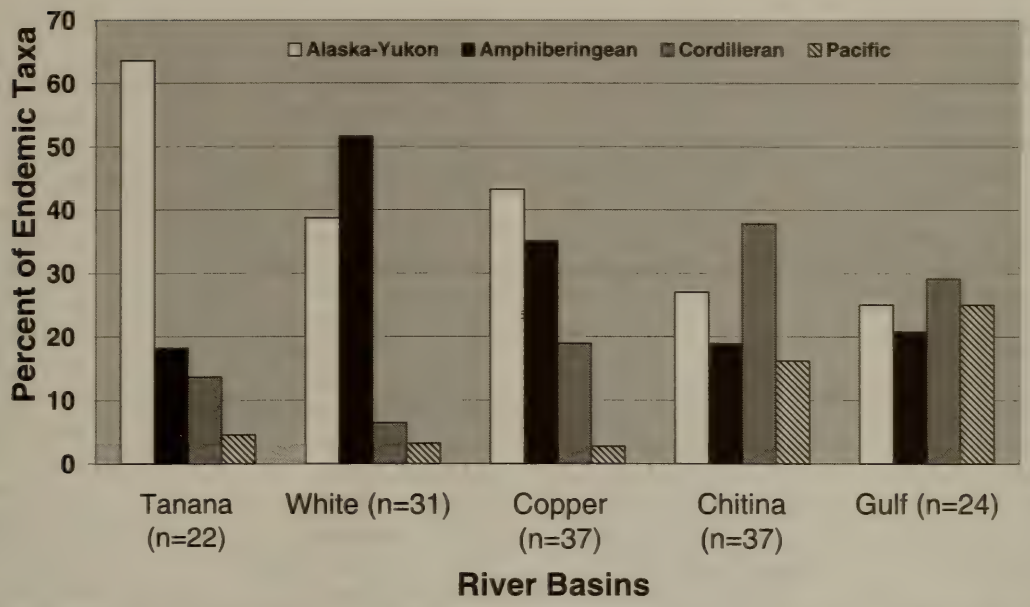


FIGURE 3. Ratio of endemic taxa within river basins and Gulf of Alaska, Wrangell-St. Elias National Park and Preserve.

However, there are many regions and communities that have yet to be surveyed or need further work. Some of these are: the Gulf of Alaska between Yakutat and Icy Bays, the southern St. Elias Mountains and Bagley Icefield, the Tanana lowlands, the White River basin, wetland and aquatic communities throughout the Park, nunataks, areas of high endemisim on the north side of the Park in the Mentasta, Nutzotin and northern Wrangell Mountains, high elevation plateaus in the Jacksina River drainage, and rare plant habitat throughout the Park.

Over half of the Park (3.9 million hectares) is designated wilderness, the remaining area (1.4 million hectares) is theoretically protected. Aircraft, motorboats and cabins are allowed in wilderness in Alaska for subsistence purposes and aircraft concessions for climbing, hiking and backpacking are not restricted in the Park. Most of the increase in backcountry use is in areas that we have found likely to harbor rare plants. The rate of global changes to ecosystems and plant communities is increasing as are infrastructure development and visitor use in the Park. Therefore, there is a need to survey areas where we anticipate use as well as the unsurveyed regions so that we can begin to assess changes to plant populations and communities. We also need information on the distribution, life history and population ecology of most rare plants so that protection plans may be developed.

Notable Collections

We documented nine additions to the flora of Alaska, 211 species new to the Park's flora, 145 range extensions greater than 200 km from previously documented localities and 186 range extensions greater than 60 km from previously documented localities. An annotated list in the phylogenetic order used by William J. Cody in the *Flora of the Yukon Territory* (1966) is preceded by a synoptic list of the most notable taxa by status. Alaska-Yukon and Park distribution maps for each species follow the annotations and are in the order of the annotations. Specimens are housed in the herbarium at Wrangell-St. Elias National Park and Preserve headquarters in Copper Center, Alaska unless otherwise indicated.

Synoptic List by Status

Taxa new to Alaska (9)

Arabis calderi
Arabis codyi
Arabis drepanoloba
Arabis lemmonii
Carex petasata
Draba lonchocarpa var. *thompsonii*
Festuca minutiflora
Najas flexilis
Trichophorum pumilum var. *rollandii*

Range Extensions (203)

Agoseris glauca
Agrostis mertensii
Agrostis thurberiana
Alopecurus alpinus
Aphragmus eschscholtzianus
Antennaria media
Arabis media
Arenaria capillaris
Arenaria longipedunculata
Arnica amplexicaulis ssp. *prima*
Arnica latifolia
Arnica mollis
Artemisia hyperborea
Aster alpinus ssp. *vierhapperi*
Aster borealis
Astragalus adsurgens ssp. *viciifolius*
Astragalus eucosmus ssp. *sealei*
Astragalus harringtonii

Astragalus nutzotinensis
Astragalus williamsii
Botrychium ascendens
Botrychium lanceolatum
Botrychium minganense
Botrychium pinnatum
Braya glabella ssp. *glabella*
Braya glabella ssp. *purpurascens*
Callitriche anceps
Callitriche hermaphroditica
Caltha leptosepala
Carex adelostoma
Carex albo-nigra
Carex buxbaumii
Carex chordorrhiza
Carex crawfordii
Carex eburnea
Carex filifolia
Carex holostoma
Carex interior
Carex krausei
Carex lasiocarpa ssp. *americana*
Carex laxa
Carex lenticularis var. *dolia*
Carex leptalea
Carex nardina
Carex nigricans
Carex obtusata
Carex parryana
Carex pauciflora
Carex petricosa
Carex phaeocephala
Carex praticola
Carex stylosa
Carex viridula
Carex williamsii
Cassiope mertensiana
Castilleja chrymactis
Castilleja elegans
Castilleja yukonis
Cerastium regelii
Ceratophyllum demersum
Chamaerhodos erecta ssp. *nutallii*
Cicuta maculata var. *angustifolia*
Cladothamnus pyrolaeflorus
Claytonia tuberosa
Collomia linearis
Colpodium vahlianum
Coptis trifolia
Cryptantha shackletteana
Cryptogramma crispa var. *sitchensis*
Cryptogramma stelleri
Cystopteris montana
Danthonia intermedia
Delphinium brachycentrum
Deschampsia brevifolia
Douglasia alaskana
Douglasia arctica
Douglasia gormanii
Draba cinerea
Draba crassifolia
Draba corymbosa
Draba densifolia
Draba incerta
Draba kananaskis
Draba lactea
Draba macounii
Draba oligosperma
Draba palanderiana
Draba porsildii
Draba ruaxes
Draba stenoloba
Draba stenopetala
Epilobium lactiflorum
Epilobium luteum
Erigeron caespitosus
Erigeron grandiflorus ssp. *arcticus*
Eriophorum callitrix
Eriophorum viridi-carinatum
Erysimum pallasii
Euphrasia mollis
Eutrema edwardsii
Fauria crista-galli
Festuca brevissima
Festuca lenensis
Festuca richardsonii
Festuca saximontana
Gentiana douglasiana
Gentiana platypetala
Gentianella tenella
Glyceria pulchella
Gymnocarpium jessoense ssp. *parvulum*
Hackelia deflexa
Halimolobos mollis
Hippuris montana
Impatiens noli-tangere
Isoetes echinospora
Juncus filiformis
Juncus mertensianus
Juniperus horizontalis
Kobresia sibirica
Kobresia simpliciuscula
Lesquerella arctica
Ligusticum scoticum ssp. *hultenii*
Lupinus kuschei
Maianthemum stellatum
Minuartia biflora
Minuartia dawsonensis
Minuartia stricta
Mitella pentandra
Montia bostockii
Myriophyllum verticillatum
Nymphaea tetragona ssp. *leibergii*
Osmorhiza depauperata
Oxytropis campestris ssp. *jordalii*
Oxytropis huddelsonii
Oxytropis scammaniana
Papaver alboroseum
Papaver radicatum ssp. *kluanense*
Papaver walpolei
Penstemon gormanii
Phacelia mollis
Phippsia algida
Phlox hoodii
Phlox richardsonii
Phyllodoce glanduliflora
Plantago eriopoda
Poa hispidula
Podagrostis aequivalis
Polystichum lonchitis

Potamogeton friesii
Potamogeton pectinatus
Potamogeton pusillus var. *pusillus*
Potamogeton praelongus
Potamogeton subsibiricus
Potamogeton zosteriformis
Potentilla arguta ssp. *convallaria*
Potentilla biflora
Potentilla diversifolia
Potentilla drummondii
Potentilla litoralis
Potentilla rubricaulis
Primula cuneifolia ssp. *saxifragifolia*
Primula egaliksensis
Puccinellia deschampsioides
Puccinellia interior
Ranunculus gelidus ssp. *grayi*
Ranunculus pacificus
Ranunculus pedatifidus ssp. *affinis*
Ranunculus sulphureus var. *sulphurus*
Ranunculus trichophyllus var. *eradicatus*
Rumex acestosa ssp. *alpestris*
Rumex beringensis
Sagina saginoides
Salix commutata
Salix rotundifolia ssp. *dodgeana*
Salix setchelliana
Salix stolonifera
Saussurea angustifolia ssp. *yukonensis*
Saxifraga adscendens ssp. *oregonensis*
Saxifraga bracteata
Saxifraga foliolosa
Selaginella sibirica
Silene involucrata ssp. *involucrata*
Silene menziesii
Silene repens
Silene uralensis ssp. *uralensis*
Silene williamsii
Smelowskia borealis
Smelowskia calycina var. *porsildii*
Sparganium minimum
Stellaria alaskana
Stellaria umbellata
Subularia aquatica
Swertia perennis
Synthyris borealis
Taraxacum carneocoloratum
Taraxacum phymatocarpum
Thlaspi arcticum
Trisetum sibiricum ssp. *litorale*
Vahlodea atropurpurea
Veronica serpyllifolia ssp. *humifusa*
Viola adunca
Viola biflora
Viola selkirkii

Alaska Natural Heritage Program State Rare Plants (State Rank < = 3) (69)
Agoseris glauca
Agrostis thurberiana
Aphragmus eschscholtzianus
Arabis calderi
Arabis codyi
Arabis drepanoloba
Arabis lemmonii
Arenaria longipedunculata
Arnica mollis
Astragalus harringtonii
Botrychium ascendens
Carex adelostoma
Carex crawfordii
Carex eburnea
Carex holostoma
Carex interior
Carex laxa
Carex lenticularis var. *dolia*
Carex parryana
Carex petasata
Cerastium regelii
Ceratophyllum demersum
Colpodium vahlianum
Cryptantha shackletteana
Cryptogramma stelleri
Cystopteris montana
Douglasia alaskana
Douglasia arctica
Douglasia gormanii
Draba densifolia
Draba incerta
Draba kananaskis
Draba lonchocarpa var. *thompsonii*
Draba porsildii
Draba ruaxes
Draba stenopetala
Eriophorum viridi-carinatum
Erysimum pallasii var. *pallasii*
Festuca lenensis
Festuca minutiflora
Glyceria pulchella
Juniperus horizontalis
Lupinus kuschei
Maianthemum stellatum
Minuartia biflora
Montia bostockii
Myriophyllum verticillatum
Najas flexilis
Oxytropis huddelsonii
Papaver alboroseum
Papaver walpolei
Phacelia mollis
Phlox hoodii
Phlox sibirica ssp. *richardsonii*
Potamogeton subsibiricus
Potentilla drummondii
Potentilla rubricaulis
Ranunculus pacificus
Rumex beringensis
Salix setchelliana
Saxifraga adscendens ssp. *oregonensis*
Smelowskia calycina var. *porsildii*
Stellaria alaskana
Stellaria umbellata
Taraxacum carneocoloratum
Thlaspi arcticum
Trichophorum pumilum var. *rollandii*
Trisetum sibiricum ssp. *litorale*
Viola selkirkii

Species Accounts

SELAGINELLACEAE

Selaginella sibirica (Milde) Hieron, Siberian Spike-Moss — CHUGACH MOUNTAINS: rare in tundra, Granitic Creek, 1768 m, 61°6.19′ N 142°55.03′ W, *M. Cook 94220A*, 8 July 1994. NUTZOTIN MOUNTAINS: scattered in rock crevices, Lick Ridge, 1554 m, 62°28.44′ N 142°15.06′ W, *M. Cook 95118*, 29 June 1995. WRANGELL MOUNTAINS: scattered on SE-facing bluff, Nabesna River, 1106 m, 62°15.05′ N 142°54.68′ W, *M. Cook 96189*, *C. Roland 96-161*, 19 June 1996; outcrop crevices, Nikolai Mine, 1695 m, 61°27′ N 142°39′ W, *Batten & Barker 96-055*, 24 July 1996; outcrop, Nikolai Ridge, 1372 m, 61°26.5′ N 142°43′ W, *Batten & Barker 96-157*, 26 July 1996 (ALA); rock ledges, Crystalline Hills, 1585 m, 61°23.59′ N 143°31.85′ W, *M. Cook 95276*, 19 July 1995; in moss under open willow scrub, Fish Creek, 1067 m, 62°16.92′ N 142°58.99′ W, *M. Cook 95312*, 27 July 1995.

This amphiberingean species occurs in dry, rocky situations throughout northern Alaska. The Granitic Creek locality extends its range 272 km to the southeast into the Chugach Mountains from a station in the Alaska Range reported by Hultén (1968). It was also collected at several intermediate localities in the Wrangell and Nutzotin Mountains. Map 1.

ISOETACEAE

Isoetes echinospora Durieu (*I. muricata* Durieu), Quillwort — WRANGELL MOUNTAINS: abundant, uprooted and lining shoreline, Lake 2870, 0.2 km N of Tanada Creek, 875 m, 62°31.38′ N 143° 28.12′ W, *C. Roland 95-096*, 28 June 1995; few clumped in muck, 0.6 m deep water, Fox Farm Lake, 727 m, 62°19.98′ N 144°50.02′ W, *M. Cook 95308*, 25 July 1995; abundant submerged in 30 cm deep water, Lake 2990′, 3.6 km west of Copper Lake, 911 m, 62°24.53′ N 143°42.68′ W, *C. Roland 96-913*, 11 August 1996.

This boreal North American aquatic species has been found at a few widely separated sites across central Alaska and the Yukon Territory. The specimens cited above extend its range 80 km southeast into the Wrangell Mountains from a station in the Alaska Range (Hultén 1968). Map 2.

OPHIOGLOSSACEAE

Botrychium ascendens W. H. Wagner, Triangle-Lobe Moonwort — NUTZOTIN MOUNTAINS: few on S-facing scree slope, Gold Hill, 1434 m, *M. Cook 3520B*, 18 July 1999.

This North American species with a cordilleran distribution was known from two localities in Alaska and one in the Yukon Territory (Cody 1994). It is rare in Alaska (G3? S1) and Cody (1994) suggested that it be added to the list of rare species for the Yukon Territory. The locality cited above extends its range 266 km to the southwest of a station in the Yukon Territory and 356 km northwest of a collection locality in the Yakutat Quad (Akwe Dunes, 59°21.78′ N 138°50.45′ W, *M.C. Stensvold 7304*, 27 June 1996 (ALA)). Map 3.

Botrychium lanceolatum (Gmel.) Angstr., Lanceleaf Grapefern — CHUGACH MOUNTAINS: rare on S-facing slopes, Juniper Island, 1346 m, 60°36.17′ N 142°14.96′ W, *C. Roland 94-208*, 10 July 1994; openings in willow thicket, Granite Creek, 823 m, 60°44′ N 142°13′ W, *Batten & Barker 96-354B*, 30 July 1996 (ALA); open low shrub birch scrub, Granite Creek, 579 m, 60°44′ N 142°32′ W, *Parker & Duffy 6718*, 6 August 1996. WRANGELL MOUNTAINS: earth-flow scar on steep S-facing slope, Nikolai Pass, 1372 m, 61°26.5′ N 142°43′ W, *Batten & Barker 96-174B*, 26 July 1996 (ALA); scattered in grassy gully, Long Glacier, 1399 m, 61°48.04′ N 144°6.27′ W, *M. Cook 96702, C. Roland 96-851*, 6 August 1996.

This moonwort occurs in maritime-influenced boreal regions and scattered inland locations throughout the circumpolar north. In Alaska, it occurs most frequently along the southern coast from the panhandle through the Aleutian Islands. Our collections extend its range 175 km northeast into the Wrangell and Chugach Mountains from a collection in the Cordova Quad (60°58′ N 145° W, *C. L. Parker 1830B*, 12 August 1986 (ALA)) and connect the distribution 202 km to the east in the Yukon Territory (Cody 1996). Map 4.

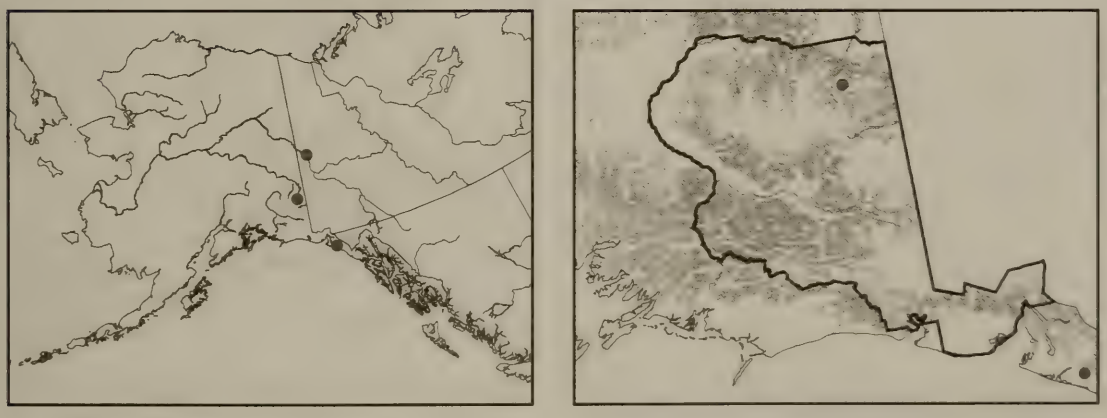
Botrychium minganense Victorin, Mingan Moonwort — NUTZOTIN MOUNTAINS: few in *Dryas*-graminoid-forb herbaceous stringer at base of scree slope, headwaters of Alder Creek, 1554 m, 62°28.44′ N 142°15.06′ W, *M. Cook 95139*, 30 June 1995; open shrub birch-willow scrub, Ptarmigan Lake, 1128 m, 61°50.12′ N 141°9.15′ W, *Duffy & Barnes 96-296*, 8 August 1996; few on S-facing scree slope, Gold Hill, 1434 m, *M. Cook 3520C*, 18 July 1999.

This moonwort occurs in scattered localities across boreal North America and as far south as Arizona in the western cordillera. It is known from only two other localities in Alaska, 405 km to the northwest in the Healy Quad (Chulitna River, 62°59.75′ N 150°6.83′ W, *C. Roland 3493B*, 18 August 1998 (ALA)) and 308 km to the southeast in the Yakutat Quad (59°19.35′ N 138°40.14′ W, *M. Stensvold 7313*, 16 July 1998 (ALA)). Map 5.

Botrychium pinnatum H. St. John (*B. boreale* (E. Fries) Milde), Northeastern Moonwort — CHUGACH MOUNTAINS: scrub thicket, Granite Creek, 1067 m, 61°5.46′ N 142°54.05′ W, *J. Bolivar 84-172*, 7 August 1984; rare in disturbed mineral soil, upper Golchonda Creek, 1402 m, 61°2.89′ N 143°24.42′ W, *M. Cook 3200*, 28 July 1998; openings in willow thicket, Granite River, 823 m, 60°44′ N 142°13′ W, *Batten & Barker 96-354C*, 30 July 1996. NUTZOTIN MOUNTAINS: few in *Dryas*-graminoid tundra, headwaters of Alder Creek, 1554 m, 62°28.44′ N 142°15.06′ W, *M. Cook 95121*, 29 June 1995. WRANGELL MOUNTAINS: scattered in meadow, vic. Chitistone Falls, 1177 m, 61°32.27′ N 142°11.49′ W, *C. Roland 96-632*, 22 July 1996; steep E-facing meadow, Nikolai Mine, 1695 m, 61°27′ N 142°39′ W, *Batten & Barker 96-074B*, 24 July 1996 (ALA);

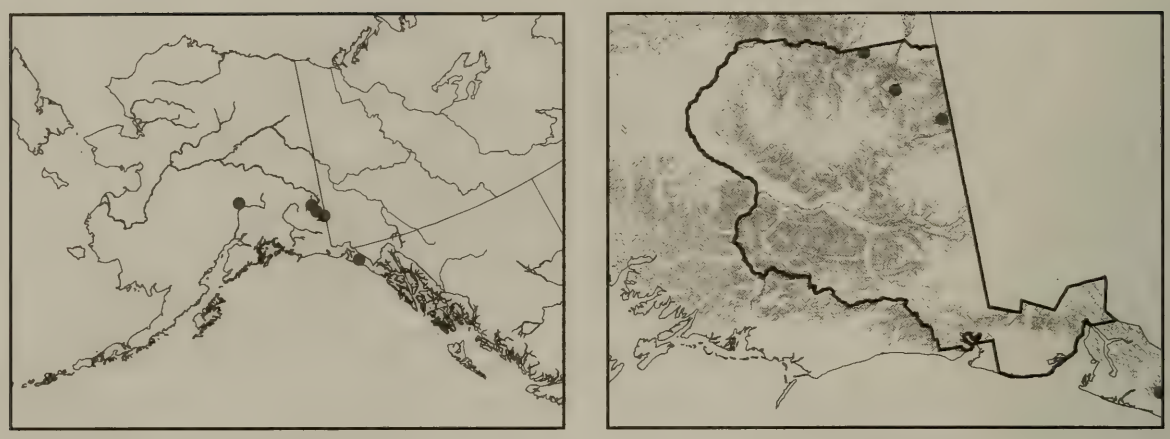
1. Selaginella sibirica

2. Isoetes echinospora



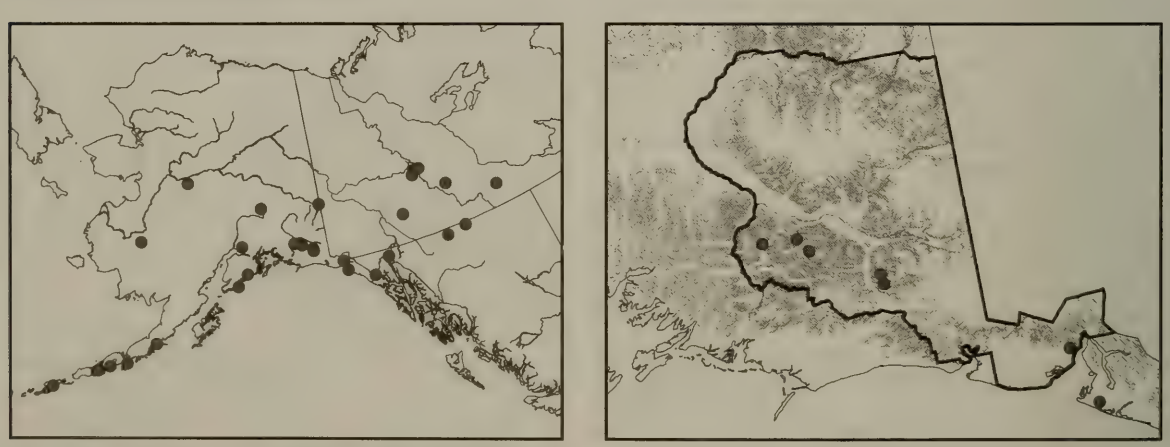
3. Botrychium ascendens

4. Botrychium lanceolatum

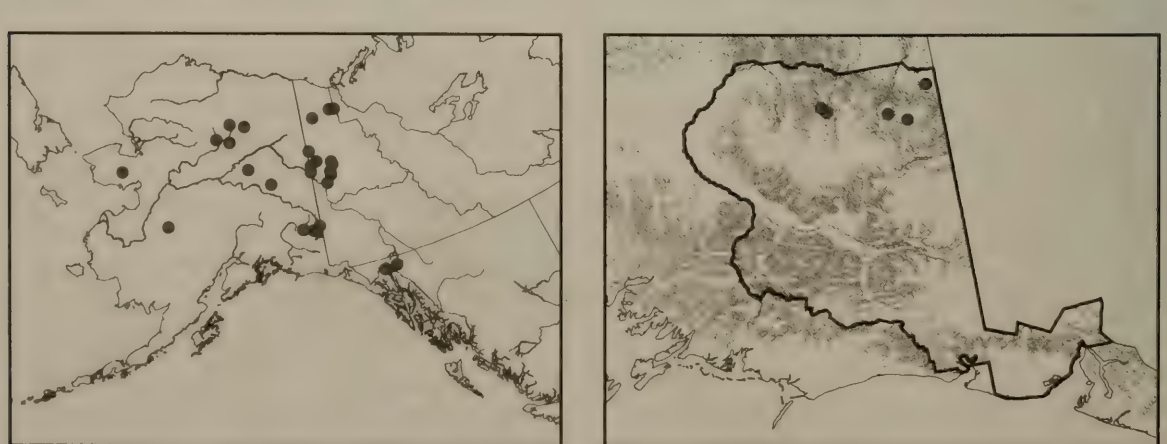


5. *Botrychium minganense*

6. *Botrychium pinnatum*

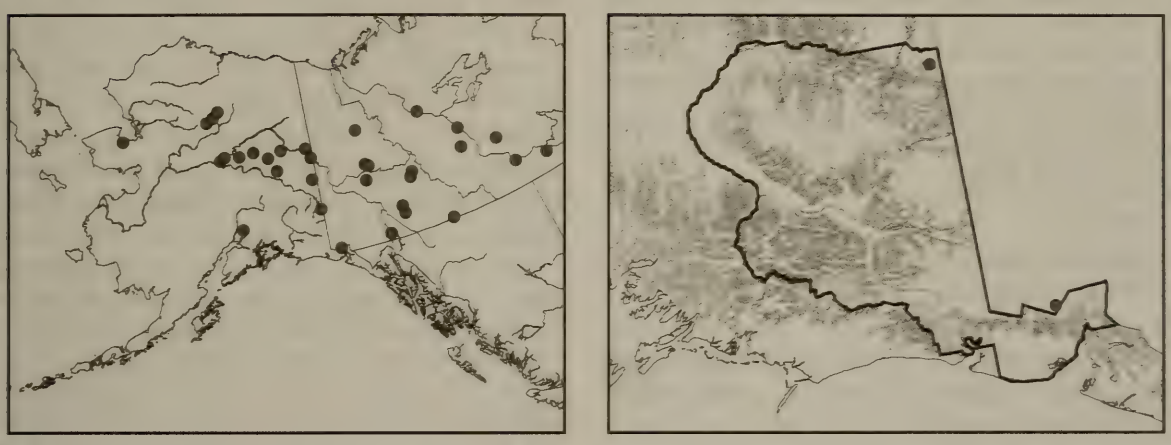


7. *Cryptogramma crispa* var. *sitchensis*



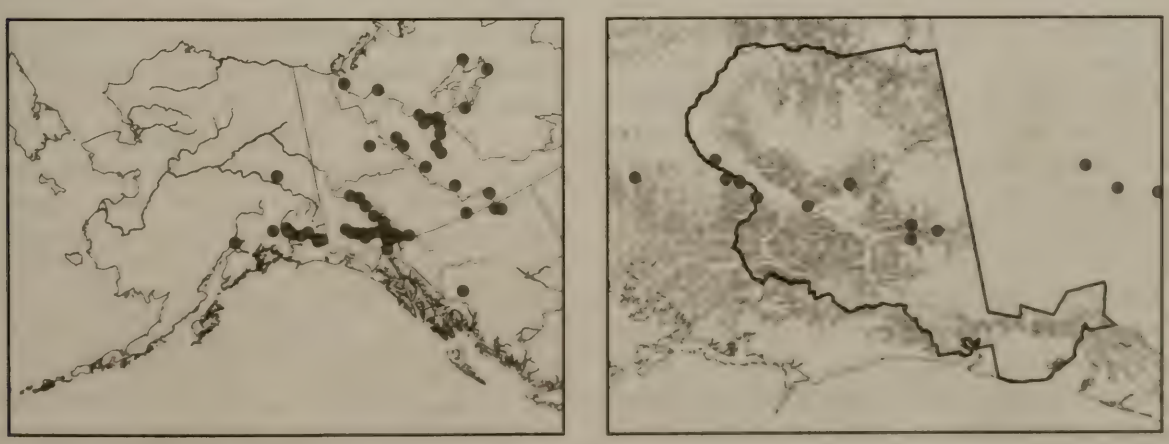
8. *Cryptogramma stelleri*

9. Cystopteris montana



10. Gymnocarpium jessoense ssp. *parvulum*

11. Polystichum lonchitis



12. Juniperus horizontalis

earthflow scar on steep slope, Nikolai Pass, 1372 m, 61°26.5' N 142°43' W, *Batten & Barker 96-174A*, 26 July 1996; moist silt near stream, W slope of Chitistone Mountain, 1219 m, 61°28' N 142°33' W, *Batten & Barker 96-146*, 26 July 1996 (ALA); patchy in bare area, vic. Long Glacier, 1399 m, 61°48.04' N 144°6.27' W, *M. Cook 96701, 96703, 96716*, 8 August 1996; few in mesic forb herbaceous vegetation, vic. Grant Creek, 1250 m, 61°17.65' N 143°56.34' W, *M. Cook 96367*, 7 July 1996.

This amphiberingean species occurs in scattered localities throughout boreal areas of North America. It was considered rare in the Yukon Territory by Douglas et al. in 1981. The collections cited above extend its range 324 km east into the Wrangell Mountains, 341 km to the northeast into the Nutzotin Mountains and 367 km east into the Chugach Mountains from a collection in the Anchorage Quad (61°50.0' N 149°18.0' W, *Parker & Murray 2097*, 10 August 1989 (ALA)). These new localities also connect the range to the west with the range 256 km to the east in the Yukon Territory. Map 6.

PTERIDACEAE

Cryptogramma crispa (L.) R. Br. var. *sitchensis* (Rupr.) C. Christens., Alaska Parsley Fern — CHUGACH MOUNTAINS: rubble slope, Granite Creek, 579 m, 60°44' N 142°32' W, *Parker & Duffy 6709*, 6 August 1996; scattered in moss, Lake Creek, 975 m, 61°11.4' N 143°49.45' W, *M. Cook 96401*, 13 July 1996; scree, Hanagita Peak, 1186 m, 61°4.91' N 143°38.86' W, *M. Cook 96421*, 14 July 1996; occasional on lateral moraine, 12 Mile Basin, 1271 m, 60°48.85' N 142°33.52' W, *M. Cook 96636*, 30 July 1996; dry boulder area, Upper Tebay Lake, 610 m, 61°11.5' N 144°23.5' W, *L. A. & E. G. Viereck 11083*, 7 July 1996. ST. ELIAS MOUNTAINS: closed tall alder scrub on glacial rubble, Atrevida Glacier, 59°57.06' N 139°48.5' W, *B. Haller s.n.*, 19 August 1987.

This fern variety is endemic to Alaska, the Yukon Territory, northern British Columbia and the District of Mackenzie, Northwest Territories where it grows in moist talus and rock crevices. The specimens cited above extend its range 293 km northeast into the Chugach Mountains from a station near Seward (Hultén 1968) and connect the range 200 km to the southeast at Yakutat (Hultén 1968). Map 7.

Cryptogramma stelleri (S.G. Gmel.) Prantl., Fragile Rock-Brake — NUTZOTIN MOUNTAINS: head of Sheep Creek, 6 km above confluence with Chisana River, 1067 m, 62°7.95' N 141°54.9' W, *J. Bolivar 84-82*, 26 June 1984; rare under boulders on SW-facing slope, Carl Creek, 1920 m, 62°3.52' N 141°36.27' W, *M. Cook 95006*, 14 June 1994; rare in rock crevices, Carden Hills, 1311 m, 62°18.44' N 141°11.55' W, *M. Cook 94166*, 25 June 1994. WRANGELL MOUNTAINS: rare in rock crevices, Monte Cristo Creek, 975 m, 62°13.66' N 142°56.35' W, *C. Roland 96-147, 96-149*, 18 June 1996; rare under boulders, Jaegar Mesa, 1893 m, 62°15.9' N 143°1.24' W, *C. Roland 95-133A*, 4 July 1995.

This fern is circumpolar and widespread but rare throughout its distribution. It is considered rare in both Alaska (G5 S2S3) and the Yukon Territory (Douglas et al. 1981). Our collections extend its range 312 km south into the Nutzotin and Wrangell Mountains from a collection in the Big Delta Quad (Brigadier Road, 64°40.75' N 146°12.38' W, *Duffy & Lipkin 95-654*, 12 July 1995 (ALA)). Map 8.

DRYOPTERIDACEAE

Cystopteris montana (Lam.) Bernh., Mountain Fragile Fern — CHUGACH MOUNTAINS: SE-facing bench, Lower Bremner River, 457 m, 61°3.39' N 144°26.8' W, *K.A. Teare 1809*, 20 July 1984. MENTASTA MOUNTAINS: scattered at forest margin toe of talus slope, Totschunda Creek, 1280 m, 62°27.85' N 142°40.68' W, *C. Roland 96-298*, 24 June 1996. WRANGELL MOUNTAINS: limestone rocks in alder thicket, Fish Creek, 1067 m, 62°16.92' N 142°58.99' W, *C. Roland 95-293*, 29 July 1995; scattered in moss-forb tundra on limestone outcrop, Lakina Glacier, 1219 m, 61°33.64' N 143°19.01' W, *C. Roland 96-689*, *M. Cook 96534*, 24 July 1996.

This fern is circumboreal and is considered rare in Alaska (G4S3) where it occurs in montane meadows and thickets, often on calcareous substrates. It had been collected in the Wrangell Mountains (Bonanza Ridge, 61°30' N 142°51' W, *Nordell & Schmitt 580*, 1976 (ALA)). The new collections cited above extend its range 114 km north into the Mentasta Mountains and 100 km south into the Chugach Mountains. Map 9.

Gymnocarpium jessoense (Koidz.) Koidz. ssp. *parvulum* Sarvela (*G. robertianum* (Hoffm.) Newm.), Limestone Oak-Fern — NUTZOTIN MOUNTAINS: rare on rock ledges under low birch/willow scrub, Carden Hills, 1311 m, 62°18.44' N 141°11.55' W, *M. Cook 94173*, 25 June 1994.

This species occurs in boreal areas throughout the circumpolar region except Greenland. In Alaska and the Yukon it is generally restricted to the central Yukon River drainage except for a single locality near Anchorage reported by Hultén (1968). It is considered rare in the Yukon Territory (Douglas et al. 1981). The specimen cited above extends its range 180 km south into the Nutzotin Mountains from a station near Chicken in the Yukon-Tanana uplands (Hultén 1968). Map 10.

Polystichum lonchitis (L.) Roth, Holly Fern — CHUGACH MOUNTAINS: rare on outcrops, E Fork Little Bremner River, 1219 m, 61°4.53' N 144°3.6' W, *L. A. & E. G. Viereck 11104*, 7 July 1996; rare on E-facing rocks of ridge, vic. Spirit Mountain, 1204 m, 61°21.09' N 144°32.4' W, *C. Roland 96-624*, 17 July 1996; scattered on S-facing talus slope, vic. 12-mile Creek, Granite Range, 1335 m, 60°49.71' N 142°33.34' W, *C. Roland 96-813*, 30 July 1996. GULF OF ALASKA: moraine, Chaix Hills, Icy Bay, 427 m, 60°7.52' N 141°8.1' W, *B. Haller s.n.*, 24 August 1987. Map 11.

This fern is circumpolar with a boreal-montane distribution and is considered rare in the Yukon Territory (Douglas

et al. 1981). Our collections extend its range 275 km southeast into the southern St. Elias Mountains from a station near Thompson Pass (61°08′ N 145° 44′ W, *C. L. Parker 2462*, 23 July 1990 (ALA)) and connect the distribution 110 km to the southeast at Yakutat (*F. Funston 126*, 15 August 1892 (US), Hultén 1941).

CUPRESSACEAE

Juniperus horizontalis Moench, Creeping Savin — CHUGACH MOUNTAINS: S-facing bank of lake, vic. East Fork Kiagna River, Granite Range, 1487 m, 60°59.5′ N 142°1′ W, *Batten & Barker 96-202*, 27 July 1996. ST. ELIAS MOUNTAINS: sandy hillside, Hubert's Landing, Chitina River, 671 m, 61°2.7′ N 141°38′ W, *D. Miquelle 84-38*, 15 July 1984; alluvial floodplain of Clear Stream, Chitina River, 488 m, 61°5.82′ N 141°57.92′ W, *Duffy & Barnes 96-005*, 8 August 1996. WRANGELL MOUNTAINS: small patch in gully within steppe, Dadina River bluff, Copper River, 393 m, 61°51.49′ N 145°0.72′ W, *C. Roland 96-304*, 1 July 1996; scattered on S-facing bluff in aspen woodland, Crystalline Hills, 602 m, 61°23.12′ N 143°36.16′ W, *M. Cook 3129*, 15 June 1998 (ALA).

This species occurs in dry situations across boreal North America but is considered rare in Alaska (G5 S1S2) where it is known only from the Copper River drainage, the vicinity of Anchorage and a single locality in the Tanana River valley. It is common on bluffs along the Chitina and middle Copper River drainages where it is often found growing with *Juniperus communis* L. It had been collected in the Wrangell Mountains (Bonanza Ridge, 61°30′ N 142°51′ W, *Nordell & Schmitt s.n.*, 1976 (LD & ALA), Nordell and Schmitt (1977) and at the head of the Chitina River (*H. M. Laing 10, 11* (CAN), Hultén (1941) and Porsild (1939). Our collections extend its range 25 km north into the Copper River valley. Map 12.

SPARGANIACEAE

Sparganium minimum (Hartm.) E. Fries (*S. natans* L.), Arctic Burr-Reed — CHUGACH MOUNTAINS: pond margin, Middle Fork of the Bremner River, 869 m, 60°55.05′ N 143°43.86′ W, *Duffy & Barnes 96-114*, 6 August 1996; mud of small dried pond, Tana River Flats, 442 m, 61°14.45′ N 142°57.21′ W, *Duffy & Barnes 96-135*, 7 August 1996; scattered in pond, upper Tebay Lake, 579 m, 61°11′ N 144°24′ W, *Parker & Gracz 6767*, 7 August 1996. WRANGELL MOUNTAINS: shallow water, vic. Tanada Creek, 927 m, 62°30.34′ N 143°25.44′ W, *Moran & Roland 95-18*, 29 June 1995.

This species is circumboreal and is considered rare in the Yukon Territory (Douglas et al. 1981). The specimens cited above extend its range 130 km south into the Wrangell Mountains from a station near Paxson (Hultén 1968) and 280 km east into the Chugach Mountains from a collection in the Anchorage Quad (Otter Lake, 61°17.53′ N 149°44.17′ W, *Duffy & Tande 1020*, 3 August 1994 (ALA)). Map 13.

POTAMOGETONACEAE

Potamogeton friesii Rupr., Fries' Pondweed — WRANGELL MOUNTAINS: abundant in small, rock-floored pond in 30-100 cm of water, Fish Creek, 1067 m, 62°16.92′ N 142°58.99′ W, *C. Roland 95-286A*, 29 July 1995.

This circumpolar species is widespread but with wide gaps. The specimen cited above extends its range 163 km northwest into the Wrangell Mountains from a station near Tonsina (Hultén 1968) Map 14.

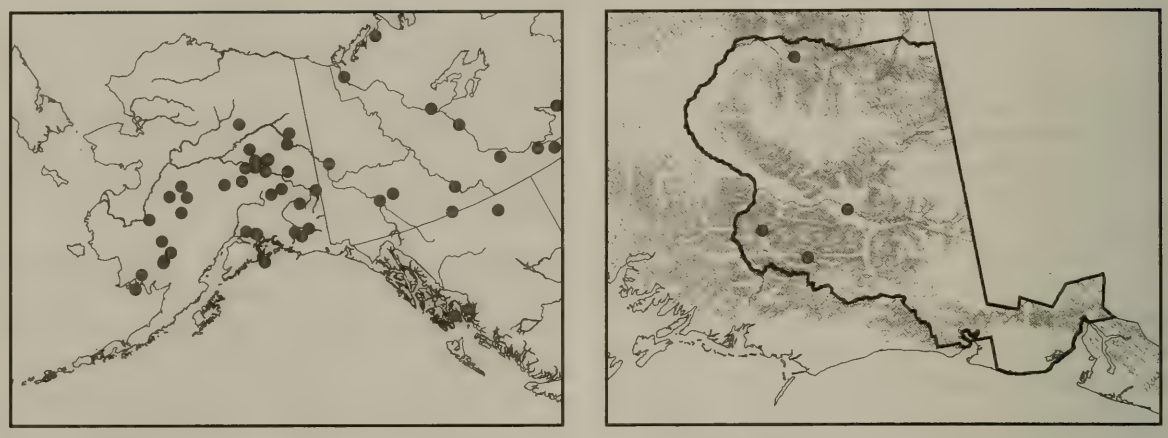
Potamogeton pectinatus L., Sago Pondweed — COPPER RIVER BASIN: floating next to shore in pond, Old Edgerton Highway, km 2.5, 415 m, 61°49.3′ N 145°10.7′ W, *M. Cook 95372*, 5 August 1995.

This locality extends the range of this pondweed 106 km east into the Copper River basin from a station in the Anchorage Quad (McRoberts Creek, 61°33.0′ N 148°55.0′ W, *Batten & Reed 80-119A*, 1 July 1980 (ALA)). Map 15

Potamogeton praelongus Wulf., White-Stemmed Pondweed — WRANGELL MOUNTAINS: Scattered in shallow water around pond, vic. Orange Hill, 884 m, 62°12.63′ N 142°52.28′ W, *C. Roland 96-121B*, 17 June 1996; shore of shallow lake, vic. Monte Cristo Creek, 1021 m, 62°14.07′ N 142°56.85′ W, *C. Roland 96-141*, 18 June 1996; common in deep water of pond, vic. of Copper Lake, 911 m, 62°24.53′ N 143°42.68′ W, *C. Roland 96-908*, 11 August 1996; common in deep water of lake, vic. Lake 2910, Copper River, 823 m, 62°26.35′ N 143°40.77′ W, *C. Roland 96-926*, 12 August 1996. CHUGACH MOUNTAINS: fresh pondweed shallows, East Flowers Lake, 404 m, 61°5.5′ N 142°34.2′ W, *Duffy & Barnes 96-205*, 8 August 1996; 1 m deep water, Chokosna Lake, 619 m, 61°27.45′ N 143°49′ W, *C. Roland 94-328A*, 10 August 1994; rooted in organic muck, Lakina Pond, 792 m, 61°29.49′ N 143°25.6′ W, *C. Roland 96-677*, 24 July 1996.

This pondweed, incompletely circumpolar and widespread in its distribution, is rare in the Yukon Territory (Douglas et al. 1981). Our collections extend its range 199 km south into the Chugach Mountains from a collection near Chistochina (62°30.0′ N 144°50.0′ W, *G. Smith 2302*, 16 May 1954 (ALA)). Map 16.

Potamogeton pusillus L. var. *pusillus* (*P. berchtoldii* Fieber), Small Pondweed — CHUGACH MOUNTAINS: mixed freshwater herbaceous, pond margin 1 m deep, Tana Flats, 442 m, 61°14.45′ N, 142°57.21′ W, *Duffy & Barnes 96-130B, 96-127, 96-122B*, 7 August 1996; floating adjacent to shore, Old Edgerton pond, 415 m, 61°49.3′ N 145°10.7′ W, *M. Cook 95374*, 5 August 1995; common in shallow water, Happel Slough, 180 m, 61°2.13′ N 144°29.43′ W, *C. Roland 96-618*, 17 July 1996. WRANGELL MOUNTAINS: beaver pond E of Chititu Creek, 457 m, 61°22.16′ N 142°40.29′ W, *M. Duffy 91043*, 8 July 1991; in 1 m deep water, Chokosna Lake, 619 m, 61°27.45′ N 143°49′ W, *C. Roland 94-328C*, 10 August 1994; common, submerged in shallow water, vic. Indian Creek, 655 m, 62°38.1′ N 144°20.2′ W, *M. Cook 95343*, 1 August 1995; rare on bottom in 30 cm deep water, Lake 2990', Copper River, 911 m, 62°24.53′



13. *Sparganium minimum*

14. *Potamogeton friesii*

15. *Potamogeton pectinatus*

16. *Potamogeton praelongus*

17. *Potamogeton pusillus* var. *pusillus*

18. *Potamogeton subsibiricus*

19. *Potamogeton zosteriformis*

20. *Najas flexilis*

N 143°42.68′ W, *C. Roland 96-909*, 11 August 1996; common rooted in muddy bottom, Copper River pond 0.5 mi E of Lake 2910′, 823 m, 62°26.35′ N 143°40.77′ W, *C. Roland 96-925*, 12 August 1996; forming dense stands throughout bottom of lake, Fish Creek, 1067 m, 62°16.92′ N 142°58.99′ W, *C. Roland 95-273*, 28 July 1995, *C. Roland 95-272*, *M. Cook 95321*, 29 July 1995.

This species is circumpolar with a widespread distribution. The specimens cited above extend its range 168 km southeast into the Wrangell Mountains from a station near Paxson (Hultén 1968) and 99 km east into the Chugach Mountains from a station near Thompson Pass (Hultén 1968). Map 17.

Potamogeton subsibiricus Hagstr., Yenisei River Pondweed — WRANGELL MOUNTAINS: rare in shallow water, Lake 2990′, upper Copper River Basin, 911 m, 62°24.53′ N 143°42.68′ W, *C. Roland 96-919*, 11 August 1996.

This amphiberingean species occurs in widely separated localities in boreal regions of Alaska and the Yukon. It is considered rare in Alaska (G3 S3) and the Yukon Territory (Douglas et al. 1981). The Copper River locality extends its range 87 km east into the Wrangell Mountains from a station along the Richardson Highway between Gakona and Paxson (Hultén 1968). Map 18.

Potamogeton zosteriformis Fern., Flatstem Pondweed — CHUGACH MOUNTAINS: common just below surface next to shore, pond at mile 1.3 Old Edgerton Highway, 415 m, 61°49.3′ N 145°10.7′ W, *M. Cook 95375*, 5 August 1995.

This North American boreal-montane species is of limted distribution in theYukon Territory (Cody 1994; Cody et al. 1998). The specimen cited above extends its range 188 km to the northwest into the Copper River basin from a locality in the Anchorage Quad (Little Kiowa Lake, 61°15.5′ N 149°39.38′ W, *Duffy & Tande 1031*, 4 August 1994 (ALA)). Map 19.

NAJADACEAE

Najas flexilis (Willdenow) Rostkov. & Schmidt, Wavy Waternymph — WRANGELL MOUNTAINS: shallow water, Chokosna Lake, 619 m, 61°27.45′ N 143°49′ W, *C. Roland 94-325*, 10 August 1994.

This species is new to the flora of Alaska and although it was collected in 1986 in the Fort Yukon Quad (Heglund Plot Lake 23, & Lake 522 near Preacher Creek, 66°01′N 144° 42′ W, *P. Heglund 86-351*, *86-363*, 16 & 17 July 1986 (ALA)), it was not reported. It is now known from a third locality in Alaska in the Anchorage Quad (Little Kiowa Lake, 61°15.48′ N 149°39.38′ W, *Duffy & Tande 1030*, 4 August 1994). The Wrangell Mountains locality is 243 km northeast of the Anchorage Quad collection site. This species has an amphiatlantic distribution, and is widespread across North America and Europe. It is now considered rare in Alaska (G5 S1S2). Map 20.

POACEAE

Agrostis mertensii Trin. (*A. borealis* Hartm.), Red Bentgrass — CHUGACH MOUNTAINS: scattered in meadow on S-facing slope, vic. Twelve-Mile Creek, 1335 m, 60°49.71′ N 142°33.34′ W, *C. Roland 96-808*, 30 July 1996; scattered in subarctic lowland sedge wet meadow, upper Tebay Lake, 579 m, 61°11′ N 144°24′ W, *Parker & Gracz 6758*, 7 August 1996. WRANGELL MOUNTAINS: scattered in lichen-heath tundra, plateau vic. Long Glacier, 1399 m, 61°48.04′ N 144°6.27′ W, *C. Roland 96-853*, *96-870*, 6 August 1996.

This species is amphiberingean with an arctic-alpine distribution. The specimens cited above extend the range 95 km south into the Chugach Mountains from a collection on Bonanza Peak in the southern Wrangell Mountains (61°30′ N 142°51′ W, *Nordell & Schmitt 490*, 1976 (LD & ALA), *Nordell & Schmitt s.n.*, 1978). The new localities connect the range 106 km to the west in the Anchorage Quad (Brilliant Glacier, 61°06′ N 147°29′ W, *M. Duffy s.n.*, 19 August 1993 (ALA)) with a locality 441 km to the southeast near Skagway (59°33.0′ N 135°06.0′ W, *A.R. Batten 88-516*, 30 August 1988 (ALA)). Map 21.

Agrostis thurberiana A. S. Hitchc. (*Podagrostis thurberiana* (Hitchc.) Hult.), Thurber's Bentgrass — CHUGACH MOUNTAINS: herbaceous meadow, under *Salix barclayi,* vic. 12-mile Creek, 1335 m, 60°49.71′ N 142°33.34′ W, *C. Roland 96-833*, 7 July 1996. GULF OF ALASKA: tall forb herbaceous slope, Amphitheather Knob, 427 m, 59°57′ N 139°46′ W, *M. Cook 87-165*, 19 August 1987.

This western North American species of Bentgrass occurs in scatterd localities along the southern coast of Alaska where it is considered rare (G5 S2). Our collections connect its range 212 km to the southwest in the Seward Quad (Iron Mountain, 60°22.00′ N 147°39.0′ W, *M. Duffy 93-1095*, 17 August 1993 (ALA)) with a station near Pelican 345 km to the southeast (Hultén 1968). Map 22.

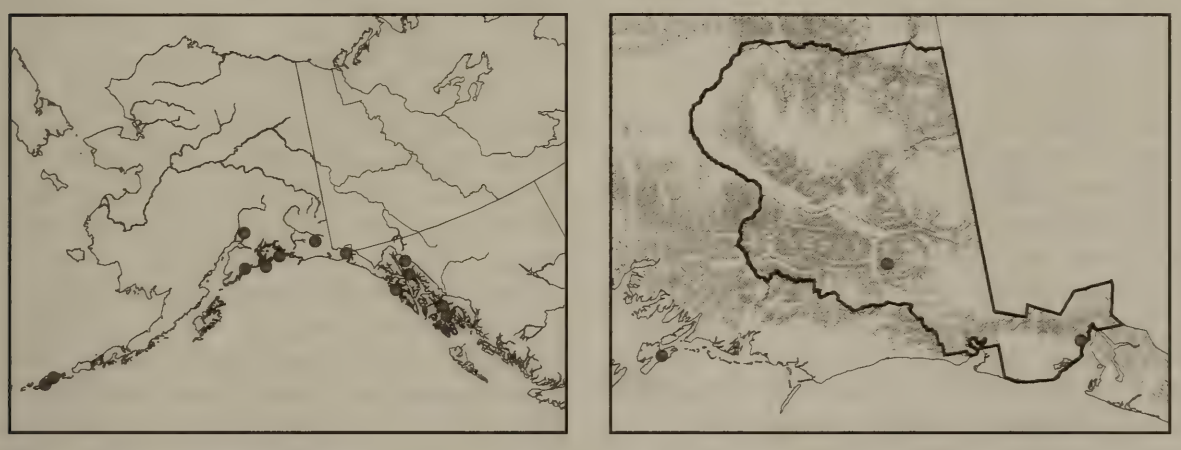
Alopecurus alpinus J.E. Smith (*A. borealis* Trin.), Mountain Foxtail — NUTZOTIN MOUNTAINS: abundant in mesic tundra on SW-facing slopes, Wiki Creek, 1411 m, 61°54.46′ N 141°10.68′ W, *C. Roland 96-088*, 10 June 1996; disturbed wet sedge meadow, Francis Creek, 1085 m, 61°51.93′ N 141°9.4′ W, *Duffy & Barnes 96-233*, 8 August 1996. WRANGELL MOUNTAINS: common in bare clay soil of frost boils, Jaegar Mesa, 1893 m, 62°15.9′ N 143°1.24′ W, *C. Roland 95-101*, 30 June 1995; Lakes Plateau, 1890 m, 62°4.4′ N 143°23.5′ W, *M. Potkin 95-115*, *95-142*, 31 July 1995.

The collections cited above extend the range of this circumpolar, arctic-alpine grass south 182 km into the Wrangell Mountains and 244 km into the Nutzotin Mountains from a station in the Tanacross Quad (W Fork of the Dennison, 63°50.00′ N 142°15.0′ W, *Smith & Viereck 2395*, 24 June 1954 (ALA)). Map 23.

Colpodium vahlianum (Liebm.) Nevski (*Puccinellia vahliana* (Liebm.) Scribn. & Merr.), Vahl's Alkalai Grass — WRANGELL MOUNTAINS: scattered in wet frost boils on limestone ridge, Cooper Pass, 1942 m, 62°17.16′ N 142°31.44′ W, *C. Roland 94-279*, 24 July 1994 (ALA).

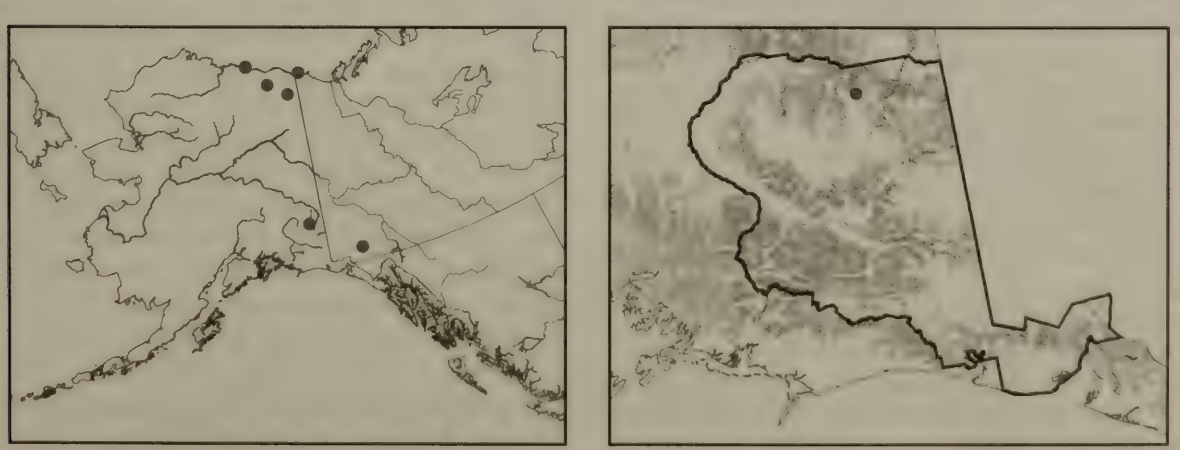
This arctic–alpine tundra grass is circumpolar and is considered rare in both Alaska (G4 S3) and the Yukon

21. Agrostis mertensii



22. Agrostis thurberiana

23. Alopecurus alpinus



24. Colpodium vahlianum

Territory (Douglas et al. 1981). The collection cited above is 719 km south of the nearest locality on the arctic coast (Table Mountain Quad: Double Mt., 68°44.00′ N 143°35.0′ W, *A.R. Batten 75-514a*, 22 July 1975 (ALA)) and 318 km west of a station in the Yukon Territory near Haines Junction (Cody 1996). Map 24.

Danthonia intermedia Vasey, Timber Wild Oat Grass — CHUGACH MOUNTAINS: abundant in turfy meadow on SE-facing slope, Granite Creek, 1829 m, 61°0.22′ N 141° 51.1′ W, *C. Roland 96-752*, 28 July 1996; abundant among heath hummocks on S-facing slope, vic 12-mile Creek, 1335 m, 60°49.71′ N 142°33.34′ W, *C. Roland 96-811*, 30 July 1996; occasional in open patches of birch scrub, Granite Creek, 884 m, 60°44.63′ N 142°6.05′ W, *M. Cook 96604*, *C. Roland 96-792*, 29 July 1996; moist herbaceous bank, Short River Pond, 503 m, 61°5.35' N 141°56.3' W, *Parker & Duffy 6687*, 6 August 1996; scattered in subarctic lowland sedge wet meadow, Falls Creek, 579 m, 61°11′ N 144°24′ W, *Parker & Gracz 6760*, 7 August 1996; mixed mesic forb herbaceous meadow & dry S-facing slope, Middle Fork of the Bremner River, 869 m, 60°55.05′ N 143°43.86′ W, *Duffy & Barnes 96-087*, *96-104*, 8 August 1996. ST. ELIAS MOUNTAINS: locally common in graminoid meadow, Blondie Ridge, 1951 m, 60°53.94′ N 141° 6.75′ W, *C. Roland 95-171*, 12 July 1995. WRANGELL MOUNTAINS: dominant in dry graminoid herbaceous meadow, Cheshnina Plateau, 1399 m, 61°48.04′ N 144°6.27′ W, *M. Cook 96715*, *C. Roland 96-848*, *96-864*, 5 August 1996; scattered in turfy meadow, Chitistone Falls, 1177 m, 61°32.27′ N 142°11.49′ W, *C. Roland 96-635*, 22 July 1996.

This species occurs in boreal meadows across North America and in Kamchatka (Hultén 1968). In Alaska, it was reported from the Kenai Peninsula and near Anchorage by Hultén (1968). Our specimens extend its range northeast 163 km into the Wrangell Mountains, 239 km into the St. Elias Mountains and 182 km into the Chugach Mountains from a collection near Cordova (60°30.93′ N 145°25.04′ W, *C. Parker 1944*, 15 August 1986 (ALA)) and connect the range 215 km to the east in the Yukon Territory near Haines Junction (Cody 1996). Map 25.

Deschampsia brevifolia R. Br. (*D. caespitosa* ssp. *brevifolia* (R. Br.) Tzvelev), Tufted Hairgrass — WRANGELL MOUNTAINS: patchy in wet graminoid tundra, vic. Sheep Glacier, 1478 m, 62°21.85′ N 144°23.73′ W, *M. Cook 94425*, 30 July 1994 (ALA); Lakes Plateau, 1890 m, 62°4.4′ N 143°23.5′ W, *M. Potkin 95-089*, 29 July 1995; few on gravel bar, Copper River near Lake 2990′, 911 m, 62°24.53′ N 143°42.68′ W, *M. Cook 96737*, 11 August 1996; scattered in openings between alders on gravel bar, vic. Batzulnetas, 640 m, 62°38.6′ N 143°52.09′ W, *M. Cook 96749*, *96752*, 13 August 1996.

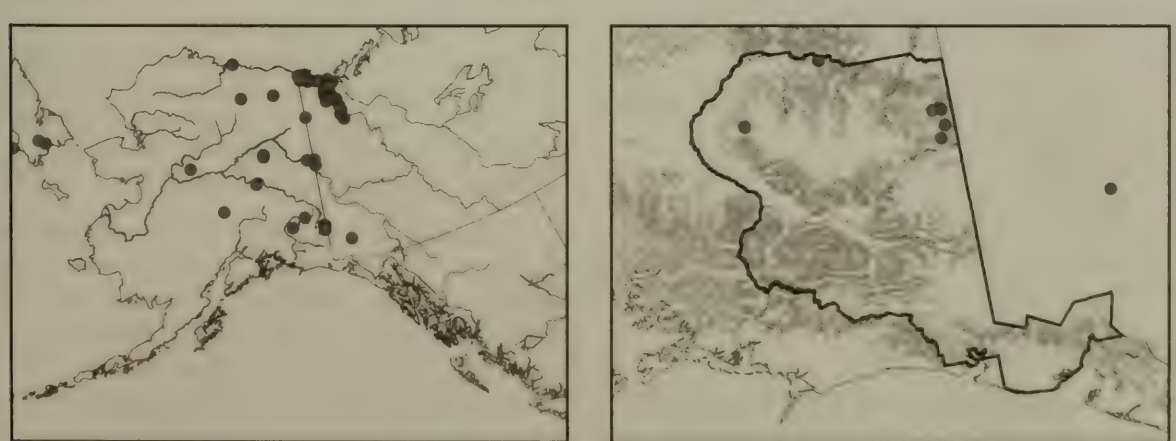
The specimens cited above extend the range of this circumpolar, arctic-alpine species 291 km south into the Wrangell Mountains from a station in the Alaska Range (Hultén 1968) and connect the range 180 km to the east in the Yukon Territory (Cody 1996). Map 26.

Festuca brevissima Jurtzev, Alaska Fescue — CHUGACH MOUNTAINS: scattered along ridge between Chakina River and Granitic Creek, 1768 m, 61°6.19′ N 142°55.03′ W, *M. Cook 94227A*, 7 July 1994. MENTASTA MOUNTAINS: bare soil of exposed creek cutbank, Lost Creek, 1722 m, 62°36.45′ N 143°12.03′ W, *Beck & Cook 95240*, 4 July 1995. NUTZOTIN MOUNTAINS: scattered in orange rhyolite scree, plateau between Bryan and Willow Creeks, 1829 m, 61°58.97′ N 141°50.03′ W, *M. Cook 95052*, 18 June 1995; occasional in moss stringers on unstable granitic rubble slope, Antler Creek, 1585 m, 62°25.78′ N 142°22.11′ W, *Cook & Beck 95103*, 27 June 1995; scattered in bare mineral soil on top of rock outcrop, alpine basin at head of Lick Creek, 1554 m, 62°28.44′ N 142°15.06′ W, *M. Cook 95125*, 29 June 1995; scattered on sheep trail along ridge, Carl Creek, 1554 m, 62°2.81′ N 141°34.65′ W, *M. Cook 3146A*, 1 July 1998 (ALA); scattered in moist gravel, Wiki Basin, 1585 m, 61°55.08′ N 141°12.07' W, *M. Cook 3178*, 15 July 1998 (ALA). WRANGELL MOUNTAINS: common in dry gravel, NE slope of Mt. Drum, 1433 m, 62°8.83′ N 144°30.18′ W, *C. Roland 94-070*, 11 June 1994; occasional on S-facing basalt outcrops, Cone Ridge, 2073 m, 62°8.21′ N 143°18.47′ W, *M. Cook 94388*, 26 July 1994; occasional in unstable S-facing rubble and cinders, Cone Ridge, 2073 m, 62°8.21′ N 143°18.47′ W, *C. Roland 94-317*, 27 July 1994; scattered in *Cassiope*-graminoid tundra on SW-facing slope, Chetaslina plateau, 1615 m, 61°56.51′ N 144°25.93′ W, *M. Cook 94478*, 16 August 1994; scattered in gravel on frost-boils, Jaegar Mesa, 1893 m, 62°15.9′ N 143°1.24′ W, *C. Roland 95-110*, *95-114*, *95-119*, *95-131*, 1 & 2 July 1995; scattered in gravel patches amongst *Dryas* tundra, Crystalline Hills, 1585 m, 61°23.59′ N 143°31.85′ W, *M. Cook 95266*, 18 July 1995; Lakes Plateau, 1890 m, 62°4.4′ N 143°23.5′ W, *M. Potkin 95-090*, 29 July 1995; moist bare mineral soil of solifluction lobes, Black Mountain, 1481 m, 62°20.85′ N 143°44.9′ W, *M. Cook 95141*, *95159*, 7 July 1995; scattered in bare gravel patches within *Cassiope*-ericaceous heath, Boulder Lake, 1036 m, 62°31.27′ N 144°11.26′ W, *M. Cook 95357*, 8 August 1995, confirmed by Signe Fredericksen (C) 1998; occasional in morainal deposits, valley between Ruddy Mountain and Mt. Drum, 1615 m, 62°4.61′ N 144°46.39′ W, *C. Roland 96-326*, 2 July 1996; N-facing scree, Nikolai Pass, 1280 m, 61°26′ N 142°40′ W, *Batten & Barker 96-008*, 23 July 1996; bouldery dry tundra on south slope, Nikolai Pass, 1280 m, 61°26′ N 142°40′ W, *Batten & Barker 96-100*, 24 July 1996 (ALA); scattered in bare, gravel-sized rhyolite scree on SE-facing slope, Kuskulana Pass, 1545 m, 61°33.72′ N 143°39.7′ W, *C. Roland 96-709*, 26 July 1996; occasional in barren, gravelly sites on SW-facing slope, Snyder Peak, 1524 m, 62°4.47′ N 144°30.51′ W, *C. Roland 96-380*, 5 July 1996.

25. Danthonia intermedia

26. Deschampsia brevifolia

27. Festuca brevissima



28. Festuca lenensis

This amphiberingean arctic-alpine species is rare in Alaska (G4 S3S4). The specimens cited above extend its range 265 km into the Chugach Mountains from a collection in the Alaska Range (Independent Ridge, 63°40.0′ N 144°54.0′ W, *L.A. Spetzman s.n.*, 20 June 1957 (ALA)). It is fairly common at high elevations in the northern region of the Park, where it was collected at numerous localities in the Mentasta, Nutzotin and Wrangell mountains. Map 27.

Festuca lenensis Drobov (*F. ovina* L. ssp. *alaskensis* Holmen), Tundra Fescue — MENTASTA MOUNTAINS: common in gravelly sites on limestone ridge in dry *Dryas octopetala* tundra, Lost Creek, 1646 m, 62°34.58′ N 143°5.58′ W, *C. Roland 94-268B*, 23 July 1994. NUTZOTIN MOUNTAINS: scattered on unstable S-facing scree slope, Horsfeld Creek, 1768 m, 62°2.88′ N 141°13.18′ W, *M. Cook 94152*, *C. Roland 94-129C*, 24 June 1994; dense population in protected, turfy tundra, Klein Creek, 1747 m, 62°2.29′ N 141°19.88′ W, *C. Roland 95-034*, 15 June 1995; scattered in fine, dry reddish soil with gravel, Wiki Creek, 1411 m, 61°54.46′ N 141°10.68′ W, *M. Cook 96041*, *96099*, *C. Roland 96-057*, 11 June 1996 (ALA); abundant in dry facies around outcrops, Rock Lake, 1119 m, 61°48.7′ N 141°16.57′ W, *C. Roland 96-038*, 6 June 1996; moist, sandy grus with seral herbs on well-vegetated SE-facing alpine colluvium, Horsfeld Creek valley, 1128 m, 62°2′ N 141°11′ W, *Parker & Gracz 6913*, 13 August 1996. WRANGELL MOUNTAINS: scattered in loose gravel on steep, SE-facing slope, NE slope of Mt. Drum, 1433 m, 62°8.83′ N 144°30.18′ W, *C. Roland 94-051*, 11 June 1994.

This amphiberingean arctic-alpine fescue is rare in Alaska (G4 S2S3) where it grows in dry, rocky situations in the subalpine and alpine zones of northern and central Alaska. In the Yukon it is known from numerous stations in the arctic but only a single locality in the southwest corner of the Territory (Cody 1996). The stations cited above extend its range southeast 310 km into the Wrangell Mountains, 320 km into the Mentasta Mountains and 450 km into the Nutzotin Moutains from collections in the Fairbanks Quad (Wood River Buttes, 64°28.35′ N 148°05.97′ W, *Duffy et al. 95-80*, *95-68*, *95-26 & 95-57*, 16 June 1995 (ALA)). These collections also connect the range to the northwest in Alaska with the range 155 km to the east in the Yukon Territory (Cody 1996). Map 28.

Festuca minutiflora Rydb., Small-Flower Fescue — CHUGACH MOUNTAINS: scattered in dry mineral soil of gravel slope, alpine valley near Hanagita Peak, 1186 m, 61°4.91′ N 143°38.86′ W, *M. Cook 96418*, 7 July 1996 (ALA).

This North American cordilleran fescue is new to the flora of Alaska. The main range of this species is in the Rocky Mountains south to California and New Mexico. It is rare in Alaska (G4 S1) and in the Yukon Territory (Douglas et al. 1981). The collection cited above is 445 km west of collections in the Yukon Territory in Kluane National Park (Cody 1996). Map 29.

Festuca richardsonii Hooker (*F. rubra* L. ssp. *richardsonii* (Hooker) Hultén, *Festuca rubra* ssp. *arctica* (Hack.) Govor.), Richardson's Fescue — NUTZOTIN MOUNTAINS: scattered in mesic graminoid stringers between closed low birch willow scrub, Beaver Lake, 1341 m, 62°2.61′ N 141°48.39′ W, *Cook & Roland 94197B*, 29 June 1994; scattered on exposed rubble slope, Wiki Creek, 1411 m, 61°54.46′ N 141°10.68′ W, *C. Roland 96-074*, 8 June 1996. WRANGELL MOUNTAINS: gravel bar, Nabesna River, 817 m, 62°18.96′ N 142°54.07′ W, *C. Roland 96-195*, 20 June 1996; occasional in sand and gravel on river terrace, Jacksina River, 759 m, 62°21.51′ N 142°52.87′ W, *C. Roland 96-202*, 21 June 1996; scattered in *Rhacomitrium* on gravel bar across from Black Mountain, 945 m, 62°19.02′ N 143°47.44′ W, *M. Cook 96720*, 8 August 1996; sandy area on the edge of alder thicket on floodplain, Mud Lake, 1001 m, 62°13.52′ N 143°45.28′ W, *C. Roland 96-893*, 9 August 1996.

This species is circumpolar with an arctic-alpine distribution. The specimens cited above connect its range 196 km to the northwest in the Alaska Range (Aiken and Darbyshire 1990) with its range 70 km to the east in the Yukon Territory (Cody 1996). Map 30.

Festuca saximontana Rydberg, Rocky Mountain Fescue — CHUGACH MOUNTAINS: open sandy White Spruce forest, Tana Dunes, 457 m, 61°4.04′ N 142°45.67′ W, *M. Duffy 91040*, 6 July 1991; common on margins of lower Tana Dunes, 488 m, 61°6.19′ N 142°55.03′ W, *M. Cook 94199*, *C. Roland 94-177A*, 7 July 1994; occasional clumps in sand of open tall alder scrub, West Fork Tana River, 448 m, 60°52.95′ N 142°48.33′ W, *M. Cook 96565*, 7 July 1996; scattered among alder-willow patches on moraine, alpine basin of 12-mile Creek, 1271 m, 60°48.85′ N 142°33.52′ W, *M. Cook 96631*, 7 July 1996 (ALA).

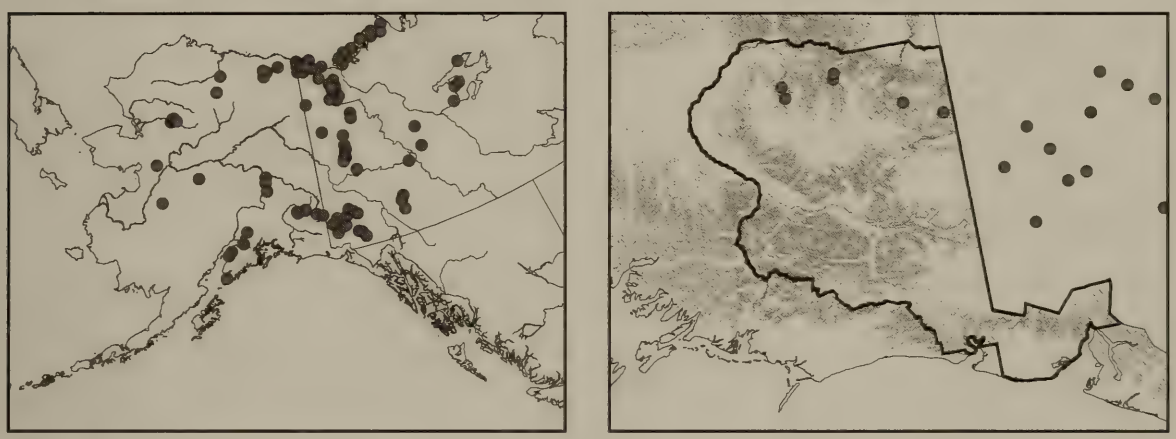
This fescue occurs across boreal North America and is found as far south as Arizona and New Mexico. Our collections extend its range 338 km south into the Chugach Mountains from a station in the Alaska Range (Hultén 1968) and connect the range 158 km to the east in the Yukon Territory (Cody 1996). Map 31.

Glyceria pulchella (Nash) K. Schum., MacKenzie Valley Mannagrass — CHUGACH MOUNTAINS: margin of meadow on river terrace wetlands, Tana River flats, 351 m, 61°12.35′ N 142°51.87′ W, *Duffy & Barnes 96-188*, 8 August 1996.

The specimen cited above extends the range of this North American boreal-montane species 337 km south into the Chugach Mountains from the Tanana Valley (Hultén 1968) and connects the range 526 km to the east in the Yukon Territory near Carcross (Cody 1996). Map 32.

Phippsia algida (Soland.) R. Br., Snow Grass — CHUGACH MOUNTAINS: scattered in wet gravel, W. Fork Goat Creek, 1487 m, 60°59.8′ N 142°11.8′ W, *M. Cook 96656*, 31 July 1996; moist seepage from snowmelt, Goat Creek, 1487 m, 60°59.5′ N 142°1′ W, *Batten & Barker 96-298*, 29 July 1996 (ALA); scattered in frost polygons, Verde Ridge, 1554 m, 61°14.03′ N 143°28.52′ W, *Roland & D'Auria 96-*

29. *Festuca minutiflora*



30. *Festuca richardsonii*

31. *Festuca saximontana*

32. *Glyceria pulchella*

488, 11 July 1996; occasional in moist calcareous gravel, Granite Creek, 1829 m, 61°0.22′ N 141°51.1′ W, *C. Roland 96-736*, 28 July 1996. WRANGELL MOUNTAINS: scattered in wet silt, Mud Lake, 1001 m, 62°13.52′ N 143°45.28′ W, *C. Roland 96-883*, 9 August 1996; rare in silt on river bar, Copper River, 847 m, 62°28.75′ N 143°38.3′ W, *C. Roland 96-934*, 12 August 1996. MENTASTA MOUNTAINS: saturated mud seep, headwaters of Lost Creek, 62°36.25′ N 143°12.08′ W, *M. Cook 3156*, 8 July 1998. NUTZOTIN MOUNTAINS: alkali lake bed, Solo Flats, 1335 m, 61°31.55′ N 141°25.3′ W, *M. Duffy 92157*, 7 July 1992. ST. ELIAS MOUNTAINS: common in wet seep, 2073 m, 60°57.74′ N 141°17.33′ W, *M. Cook 95226*, *C. Roland 95-192*, 14 July 1995. WRANGELL MOUNTAINS: rare in moist organic soil, Cone Ridge, 2073 m, 62°8.21′ N 143°18.47′ W, *M. Cook 94367*, *C. Roland 94-308*, 25 July 1994; occasional in moss, Chetaslina Ridge, 1615 m, 61°56.51′ N 144°25.93′ W, *M. Cook 94470*, 15 August 1994; frost scars, VABM Sentinel, 1829 m, 61°39′ N 142°32′ W, *Batten & Barker 96-107*, 24 July 1996; moist sand along rivulet, Skolai Creek, 1341 m, 61°41.5′ N 142°23′ W, *Batten & Barker 96-126*, 25 July 1996; common in mossy soil in seep, Hasen Creek, 1835 m, 61°34.06′ N 142°18.33′ W, *C. Roland 96-637*, 23 July 1996; locally abundant in saturated soils, Grotto Creek, 1661 m, 61°30.56′ N 142°24.79′ W, *C. Roland 96-657*, 23 July 1996; Lakes Plateau, 1890 m, 62°4.4' N 143°23.5′ W, *Leggett & Potkin 95-138, 95-108*, 28 July 1995; abundant in streambed, Jaegar Mesa, 1893 m, 62°15.9′ N 143°1.24′ W, *C. Roland 95-106*, 30 June 1995; common in seep, Cooper Mountain, 1942 m, 62°17.16′ N 142°31.44′ W, *C. Roland 94-281*, 24 July 1994.

This circumpolar arctic-alpine tundra grass is rare in the Yukon Territory (Douglas et al. 1981). It had been collected in the Wrangell Mountains at Chitistone Pass (Scott 1968). The collections cited above extend its range 127 km into the Chugach Mountains and 135 km into the western Wrangell Mountains. Map 33.

Poa hispidula Vasey (*P. macrocalyx* Trautv. & C.A. Mey.), Large Glume Blue Grass — CHUGACH MOUNTAINS: common in clumps on boulder strewn area on lower Tana Dunes, 488 m, 61°6.19′ N 142°55.03′ W, *M. Cook 94201, 94202*, *C. Roland 94-177C*, 7 July 1994; scattered in saturated, mossy fen, vic. Middle Hanagita Lake, 744 m, 61°11.58′ N 143°30.49′ W, *Roland & D'Auria 96-498*, 12 July 1996. WRANGELL MOUNTAINS: mesic graminoid-dwarf scrub tundra, Black Mountain, 1481 m, 62°20.85′ N 143°44.9′ W, *M. Cook 95160*, 3 July 1995.

The specimens cited above represent the northern limit of the range of this grass. It is an Alaska-Yukon endemic, known from numerous localities along the southern coast and the Aleutian Islands. These collections extend its range 289 km east into the Chugach Mountains and 264 km northeast into the Wrangell Mountains from a collection in the Anchorage Quad (Ft. Richardson, 61°15.45′ N 149°39.42′ W, *Duffy & Tande 1008*, 2 August 1994 (ALA)) and connect the range 406 km to the southeast near Skagway (Hultén 1968). Map 34.

Podagrostis aequivalis (Trin.) Scribn. & Merr. (*Agrostis aequivalvis* (Trin.) Trin.), Northern Bentgrass — WRANGELL MOUNTAINS: rare on floodplain of the Dadina River, 393 m, 61°51.49' N 145°0.72' W, *C. Roland 96-308*, 1 July 1996.

The Wrangell Mountains locality represents the northern limit of the range of this species, which occurs along the west coast of North America, from Oregon to the south coast of Alaska. This locality extends the range of this species 133 km north into the Wrangell Mountains from a station near Cordova (Hultén 1968). Map 35.

Puccinellia deschampsioides Sorens., Polar Alkalai Grass — WRANGELL MOUNTAINS: near shoreline in wet clay, Mt. Drum warm spring, 897 m, 62°4.83′ N 145°0.55′ W, *C.R. Meyers 84-90*, 18 July 1984; sparsely vegetated berm surrounding Lower Klawasi Mud volcano, 62°3.52′ N 145°13.29′ W, *M. Cook 91203, 91204*, 21 August 1991.

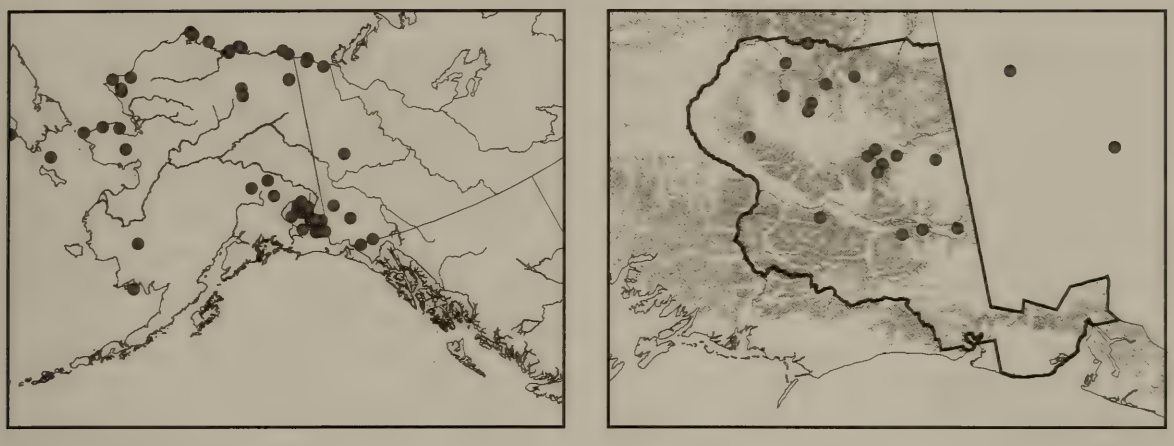
This halophytic grass is found in disjunct stations across northern North America and western Greenland. The Mt. Drum localities represent its western range limit. These stations are 358 km west of a station in the Yukon Territory (Cody 1996) where it is considered rare (Douglas et al. 1981). Map 36.

Puccinellia interior Sorens., Inland Alkalai Grass — NUTZOTIN MOUNTAINS: infrequent in saturated moss and standing water in graminoid dominated marsh adjacent to Ptarmigan Lake airstrip, 1052 m, 61°52.01′ N 141°10.28′ W, *M. Cook 3198A*, 17 July 1998.

This species is endemic to Alaska and the Yukon where it occurs in moist meadows. It is known from east and south–central Alaska and the southern half of Yukon Territory, where it is considered rare (Douglas et al. 1981). It was collected in the vicinity of the Park at Copper Center (*C.W. Heideman 2*, 1908 (US); *J.P. Anderson 2734*, 1935 (H)) and at Chitina (*J.P. Anderson 2028*, 7 July 1935 (H)) (Hultén 1941-1950). Our collection connects the distribution from a point 76 km to the east in the Yukon Territory (Cody 1996) with those cited above, approximately 222 km to the west. Map 37.

Trisetum sibiricum Rupr. ssp. *litorale* (Rupr.) Roshev., Siberian Oatgrass — NUTZOTIN MOUNTAINS: S-facing scree slope, 2.4 km west of Ptarmigan Creek, 1494 m, 61°32.89′ N 141°3.28′ W, *M. Cook 92482*, 9 August 1992; steep S-facing rhyolite scree knob, west side of Wiki Creek, 1524 m, 61°54.77′ N 141°11.05′ W, *M. Cook 3190*, 15 July 1998 (ALA).

This amphiberingean species occurs throughout northern Asia, but in North America is restricted to Alaska and a few sites in westernmost Yukon Territory where it is considered very rare (Douglas et al. 1981). This grass is also considered rare in Alaska (G5T4Q S2). Our collections extend its range 515 km south into the Nutzotin Mountains and represent the southern limit of its distribution in North America. Map 38.



33. Phippsia algida

34. Poa hispidula

35. Podagrostis aequivalis

36. Puccinellia deschampsioides

Vahlodea atropurpurea (Wahlenb.) E. Fries, Mountain Hairgrass — GULF OF ALASKA: mesic tall mixed forb herbaceous meadow, Amphitheater Knob, 427 m, 59°57′ N 139°46′ W, *M. Cook 87-88*, 19 August 1987; mixed herbaceous meadow, Karr Hills, 549 m, 60°8.66′ N 141°16.44′ W, *K. Beck 87-7*, 12 August 1987; heather alpine tundra, Floral Pass, 792 m, 59°57.91′ N 139°57.76′ W, *M. Cook 87-100*, 21 August 1987; Samovar Hills, 518 m, 60°9.3′ N 140°38′ W, *M. Cook 87-105*, 23 August 1987. CHUGACH MOUNTAINS: moist soil in *Betula glandulosa* thicket, Martin Creek, 60°56′ N 142°23′ W, *Batten & Barker 96-260*, 28 July 1996; scattered in tall forb herbaceous meadow, Granite Creek, 1344 m, 60°46.44′ n 142°5.12′ W, *C. Roland 96-805b*, *96-804b*, *M. Cook 96224*, 29 July 1996; common in *Empetrum* heath, 12-Mile Creek, 988 m, 60°50.51′ N 142°23.02′ W, *C. Roland 96-764*, 29 July 1996; common in subarctic lowland sedge wet meadow, upper Tebay Lake, 579 m, 61°11′ N 144°24′ W, *Parker & Gracz 6769, 6778*, 7 August 1996. WRANGELL MOUNTAINS: patchy in mesic low willow forb herbaceous vegetation, Lakina Glacier, 1219 m, 61°33.64′ N 143°19.01′ W, *M. Cook 96540*, *C. Roland 96-700*, 25 July 1996; patchy along shore of lake in *Empetrum* heath, Cheshnina Plateau, 1399 m, 61°48.04′ N 144°6.27′ W, *M. Cook 96717*, 8 August 1996. ST. ELIAS MOUNTAINS: open low shrub, Short River Pond, 503 m, 61°5.35′ N 141°56.3′ W, *Parker & Duffy 6695*, 6 August 1996.

Vahlodea atropurpurea sens. lat. occurs in meadows and thickets throughout the circumpolar north with large gaps (Cody 1996). The specimens cited above extend its range 401 km to the south into the southern St. Elias Mountains from a station near Slana (Hultén 1968) and connect the western range with a station 385 km to the southeast in the Sitka Quad (Freshwater Creek, 58°0.06′ N 134°49.57′ W, *C.L. Parker 5251*, 14 July 1994 (ALA)). Map 39.

CYPERACEAE

Carex adelostoma Krecz., Circumpolar Sedge — WRANGELL MOUNTAINS: Fox Farm Lakes, 727 m, 62°19.98′ N 144°50.02′ W, *M. Potkin 95-008*, 26 July 1995; patchy in mesic graminoid herbaceous vegetation, vic. Copper Lake, 911 m, 62°24.53′ N 143°42.68′ W, *M. Cook 96732*, 8 August 1996.

Carex adelostoma was collected by A. Dutilly, E. Lepage and O'Neil near Long Lake on the Nabesna Road in 1947 (Lepage 1951; Hultén 1967). Our two collection localities are nearby in the upper Copper River watershed. These three collections represent the only known localities in Alaska and form the western range limit of this species in North America. This sedge is rare in Alaska (G4 S1) and has an interrupted distribution throughout its range. The closest station is 988 km to the northeast at Great Bear Lake in the Northwest Territories (Porsild and Cody 1980). Map 40.

Carex albo-nigra Mack., Black-and-White-Scale Sedge — CHUGACH MOUNTAINS: S-facing boulder slope in unstable gravel scree, Juniper Island, 1291 m, 60°36.24′ N 142°21.69′ W, *M. Cook 94264*, 11 July 1994. MENTASTA MOUNTAINS: scattered in *Arctostaphylos uva-ursi/Festuca altaica* meadow on S-facing slope, 1097 m, 62°33.3′ N 143°9′ W, *Roland & D'Auria 97-042*, 26 June 1997; common in dry, White Spruce forest at base of bluff, Lost Creek, 1097 m, 62°33.3′ N 143°9′ W, *Roland & D'Auria 97-077*, 26 June 1997. NUTZOTIN MOUNTAINS: occasional on lower slopes in *Potentilla fruticosa/Arctostaphylos uva-ursi* community, Carl Creek, 1920 m, 62°3.52′ N 141°36.27′ W, *C. Roland 95-043*, 20 June 1994; crevices of boulder outcrops on S-facing slope, ridge 0.6 km E of Rocker & Ptarmigan Creek confluence, 1433 m, 61°54.8′ N 141°2.03′ W, *M. Cook 94142A*, 23 June 1994; patchy in talus meadow of S-facing slope, Rock Lake, 1119 m, 61°48.7′ N 141°16.57′ W, *C. Roland 96-034*, 5 June 1996. WRANGELL MOUNTAINS: wet graminoid-dwarf willow-bryoid tundra, ridge between Chichokna and Chetaslina Rivers, 1615 m, 61°56.51′ N 144°25.93′ W, *M. Cook 94470A*, 15 August 1994.

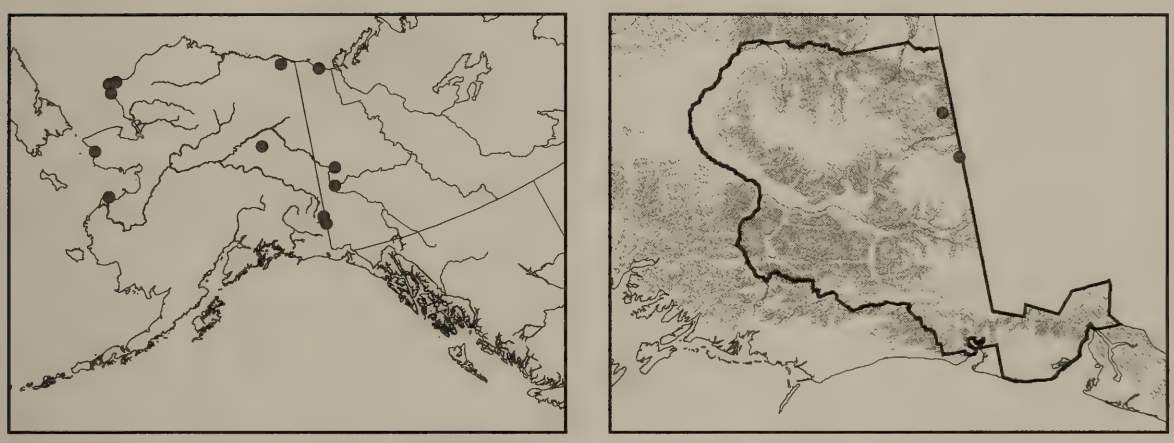
This sedge occurs on dry hillsides and talus meadows into the subalpine region in eastern Alaska. It is endemic to the cordilleran region of western North America, where it occurs from New Mexico, Arizona and California northward into eastern Alaska. It is considered rare in the Yukon Territory where it is known from fewer than ten sites (Douglas et al. 1981). Our collections extend its range 299 km southeast into the Nutzotin Mountains and 365 km into the Chugach Mountains from a locality in the Alaska Range (Black Rapids Roadhouse, 63°32.0′ N 145°51.0′ W, *Batten et al. 78-4*, 28 June 1978 (ALA)). Map 41.

Carex buxbaumii Wahlenb., Buxbaum's Sedge — CHUGACH MOUNTAINS: sedge meadow, Upper Tebay Lake, 579 m, 61°11.5′ N 144°23′ W, *L. A. & E. G. Viereck 11093*, 15 July 1996; rare in sedge herb meadow, Tebay Lake, 579 m, 61°11′ N 144°24′ W, *Parker & Gracz 6740*, 7 August 1996. NUTZOTIN MOUNTAINS: patchy in sphagnum bog, Lick Creek, 914 m, 62°28.89′ N 142°7.56′ W, *M. Cook 95111*, 28 June 1995. WRANGELL MOUNTAINS: patchy in mesic graminoid herbaceous-open low willow scrub gulley, vic. of Whitham Lake, 936 m, 62°19.33′ N 142°53.28′ W, *M. Cook 96200*, 6 June 1996; abundant at edge of pond, Lakina river, 792 m, 61°29.49′ N 143°25.6′ W, *C. Roland 96-678*, 24 July 1996; occasional in marsh, Dadina River, 744 m, 61°53.05′ N 144°44.09′ W, *M. Cook 96276A*, *C. Roland 96-344*, 2 July 1996.

This sedge is found in swamps and bogs at low elevations across boreal regions of the circumpolar north. However, it is absent from the Russian Far-East according to Hultén (1968). In North America, it occurs as far south as Georgia in the east and California in the west. It is of limited distribution in the Yukon Territory (Cody 1996). The localities cited above extend its range 189 km to the south into the Chugach Mountains from a station near Mentasta reported by Hultén (1968). Map 42.

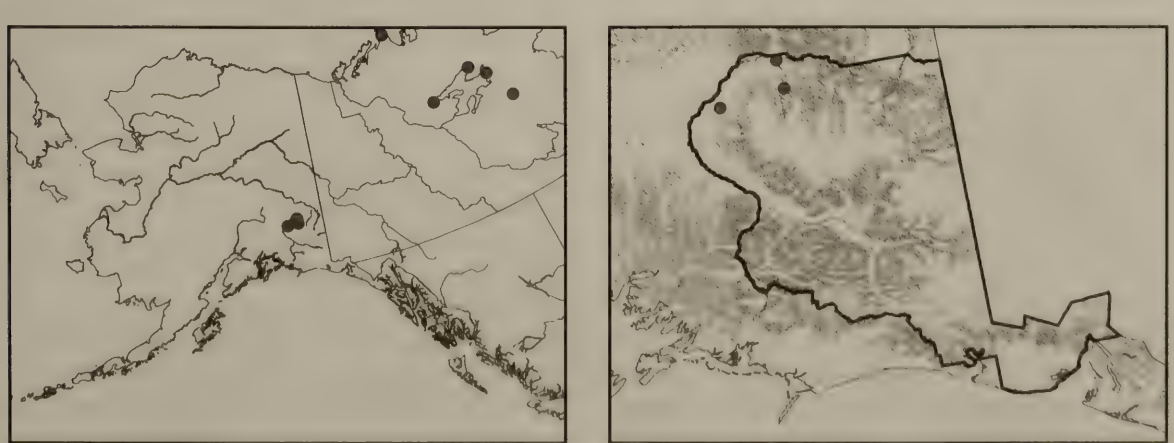
Carex chordorrhiza Ehrh. ex. L. f., Creeping Sedge — CHUGACH MOUNTAINS: sweetgale/graminoid bog,

37. Puccinellia interior



38. Trisetum sibiricum ssp. *litorale*

39. Vahlodea atropurpurea



40. Carex adelostoma

Tana River flats, 411 m, 61°12.59′ N 142°54.47′ W, *Duffy & Barnes 96-194*, 8 August 1996. WRANGELL MOUNTAINS: numerous in quaking bog, Indian Lake, 655 m, 62°38.1′ N 144°20.2′ W, *M. Cook 95347*, 1 August 1995; locally dominant in wet sedge meadow, vic. Monte Cristo Creek, 1067 m, 62°14.27′ N 142°55.81′ W, *C. Roland 96-136*, 18 June 1996; co-dominant in sedge marsh, Kuskulana River, 509 m, 61°28.53′ N 143°50.77′ W, *C. Roland 96-722*, 26 July 1996.

This sedge occurs in bogs and lake margins from the lowlands into the subalpine region in Alaska. Its range is circumpolar, but in North Ameica it is generally restricted to the boreal region and northward, reaching its southern range limit in isolated localities in Illinois. Our collections form a range connection for this sedge between a station in the Yukon Territory 255 km to the east (Cody 1996) and a locality in the Anchorage Quad 226 km to the west (Jim and Swan Lakes, 61°33.0′ N 148°55.0′ W, *Batten & Reed 80-115*, 1 July 1980 (ALA)). Map 43.

Carex crawfordii Fern., Crawford's Sedge — CHUGACH MOUNTAINS: dry pond meadow, Tana River flats, 442 m, 61°14.45′ N 142°57.21′ W, *Duffy & Barnes 96-140*, 8 August 1996.

This sedge occurs across boreal North America and reaches its southern range limit in Missouri (Kartesz 1999). It is rare in Alaska (G5 S2S3) and in the Yukon Territory (Douglas et al. 1981). The closest collection localities to the Tana River are a station near Delta Junction (141 km north) and a station near Anchorage 331 km to the west (Hultén 1968). Map 44.

Carex eburnea Boott, Bristleleaf Sedge — ST. ELIAS MOUNTAINS: White Spruce woodland, Clear Stream, 488 m, 61°5.82′ N 141°57.92′ W, *Duffy & Barnes 96-001*, 8 August 1996. WRANGELL MOUNTAINS: patchy in sedge meadow, Grizzly Lake, 1000 m, 62°19.51′ N 143°9.24′ W, *Cook & Allen 3551*, 26 July 2000.

These collections extend the range of this North American boreal-montane sedge 182 km south into the Wrangell Mountains from the Alaska Range (Hultén 1968). It had been collected near Chitina (Hultén 1968) and at the head of the Chitina River (*H.M. Laing s.n.*, 18 June 1925 (CAN), Hultén 1941-1950, Porsild 1939). It is rare in Alaska (G5 S2S3) and in the Yukon Territory (Douglas et al. 1981). Map 45.

Carex filifolia Nutt., Thread-Leaf sedge — CHUGACH MOUNTAINS: steep, SE-facing bluff, confluence of Copper and Chitina Rivers, 152 m, 61°31.55′ N 144°24.85′ W, *C. Roland 94-074B*, 12 June 1994; steep SW-facing scree slope, Goat Creek, 1487 m, 60°59.5′ N 142°1′ W, *Batten & Barker 96-187B, 96-224*, 27 & 28 July 1996. MENTASTA MOUNTAINS: rare in *Arctostaphylos uva-ursi* mats on S-facing slope, Devil's Mountain, 942 m, 62°24.95′ N 142°54.86′ W, *C. Roland 96-231*, 22 June 1996. NUTZOTIN MOUNTAINS: abundant on steep, S-facing bluff, White River between Cub and Traver Creeks, 1219 m, 61°44.3′ N 141°9.5′ W, *C. Roland 95-078*, 21 June 1995; occasional in well drained areas on limestone, Mt. Natazhat, 1716 m, 61°35.38′ N 141°1.83′ W, *C. Roland 95-060*, 19 June 1995. ST. ELIAS MOUNTAINS: dry sandy mineral soil, vic. Walsh Glacier, 1951 m, 60°53.94′ N 141°6.75′ W, *M. Cook 95222*, 15 July 1995.

Carex filifolia occurs throughout the western half of North America, reaching its eastern limit in Manitoba, Canada and its southern limit in New Mexico. It occurs on xeric slopes and prairies, and only reaches into eastern Alaska, where Hultén reported it from two localities, one near Chitina (*D.F. Murray, B.A. Murray and A.P. Khokhryakov s.n.*, 61°30.0′ N 144°25.0′ W, 8 July 1981 (ALA)) and another in the Tanana River valley east of Fairbanks. Our collections extend its range into the Nutzotin, Chugach, St. Elias and Wrangell Mountains. Map 46.

Carex holostoma Drej., Arctic Marsh Sedge — NUTZOTIN MOUNTAINS: occasional in open low mixed shrub sedge tundra bog, Horsfeld Creek, 1097 m, 62°1′ N 141°11′ W, *Parker & Gracz 6857A*, 10 August 1996.

The specimen cited above extends the range of this sedge 134 km east into the Nutzotin Mountains from a collection made by A. Dutilly, E. Lepage and O'Neil near Long Lake on the Nabesna Road in 1947 (Lepage 1951; Hultén 1967). These collections document the southern limit of its range, which is 833 km south of collections on the arctic coast of Alaska (Mt. Michelson Quad, Kavik R., 69°41.0′ N 146°52.0′ W, *M. Emers s.n.*, 2 July 1992 (ALA)). This sedge is rare in Alaska (G3G4 S2) and in the Yukon Territory (Douglas et al. 1981). Map 47.

Carex interior Bailey, Inland Sedge — CHUGACH MOUNTAINS: occasional in open mossy areas, West Fork Tana River, 448 m, 60°52.95′ N 142°48.33′ W, *M. Cook 96567*, 7 July 1996 (ALA).

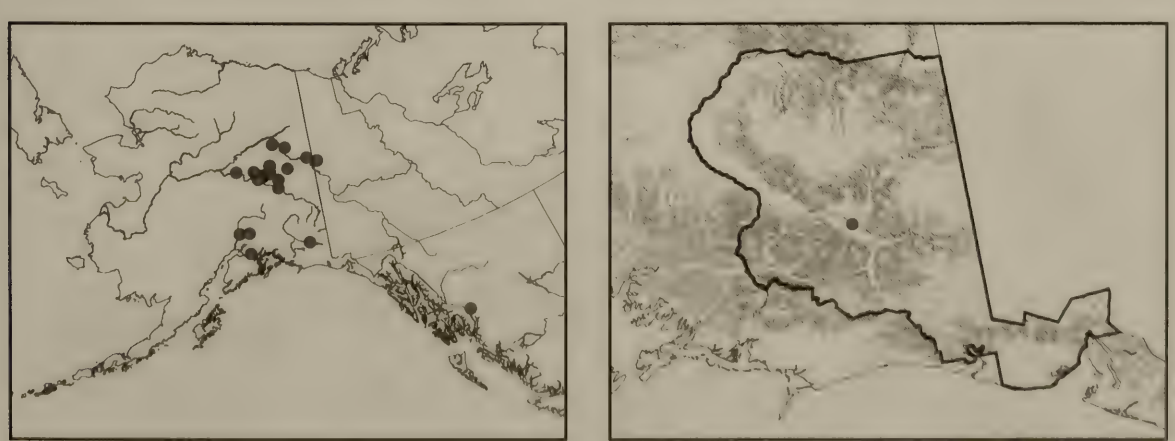
This sedge is disjunct from the temperate zone and is rare in Alaska (G5 S1) and in the Yukon Territory (Douglas et al. 1981). The specimen cited above extends its range 288 km east into the Chugach Mountains from a station in the Anchorage Quad (Baxter Bog, 61°13.0′ N 149°54.0′ W, *E. F. Layser 3275*, July 1984 (ALA)). Map 48.

Carex krausei Boeck., Krause's Sedge — CHUGACH MOUNTAINS: wet sedge meadow on low terrace, Kiagna River, 762 m, 60°58.33′ N 142°20′ W, *Batten & Barker 96-239*, 28 July 1996. MENTASTA MOUNTAINS: landslide on W end of Soda Lake, 1173 m, 62°32.36′ N 142°53.98′ W, *M. Cook 94306B*, 21 July 1994; occasional in wet sand in openings of *Populus trichocarpa/Salix alaxensis* woodland, Totschunda Creek, 725 m, 62°26.94′ N 42°40.8′ W, *M. Cook 96254*, 6 June 1996. NUTZOTIN MOUNTAINS: scattered under *Salix pulchra*, upper Flat Creek, 1323 m, 61°58.97′ N 141°41.25′ W, *M. Cook 95036*, 17 June 1995; ST. ELIAS MOUNTAINS: open low willow scrub, Clear Stream, 488 m, 61°5.82′ N 141°57.92′ W, *Duffy & Barnes 96-029, 96-030, 96-031*, 8 August 1996. WRANGELL MOUNTAINS: few in bare gravel patches, vic. Boulder Creek, 1036 m, 62°31.27′ N 144°11.26′ W, *M. Cook 95359*, 2 August 1995; occasional in moist silt of abandoned river channel, vic. Black Mountain, 945 m,

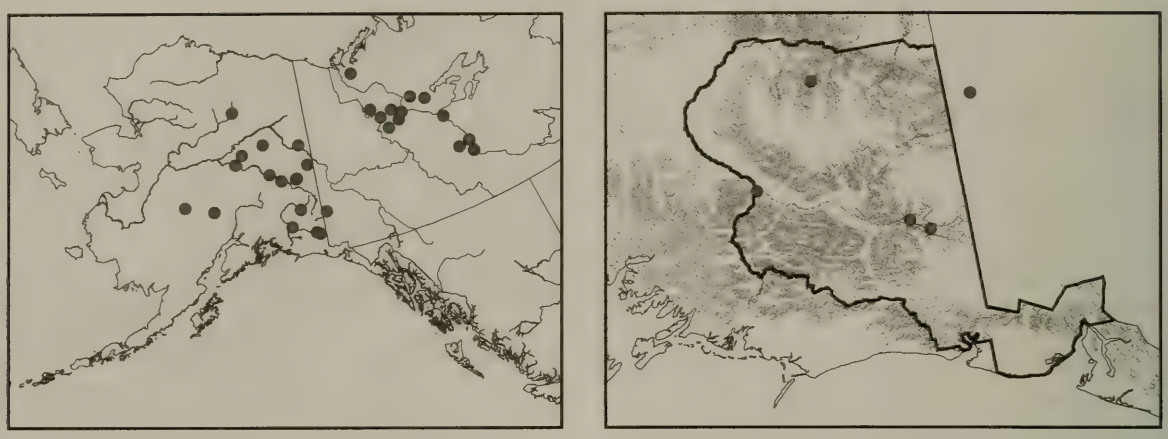
41. Carex albo-nigra

42. Carex buxbaumii

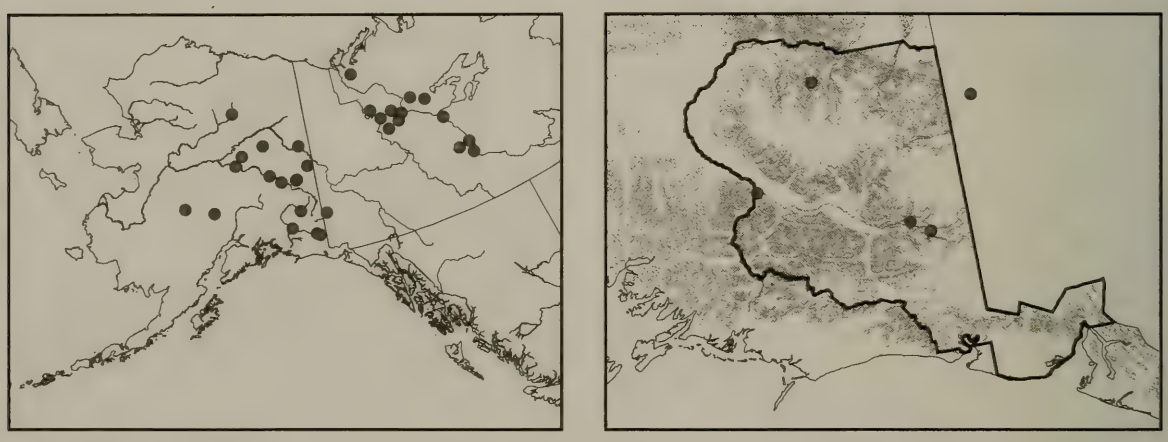
43. Carex chordorrhiza



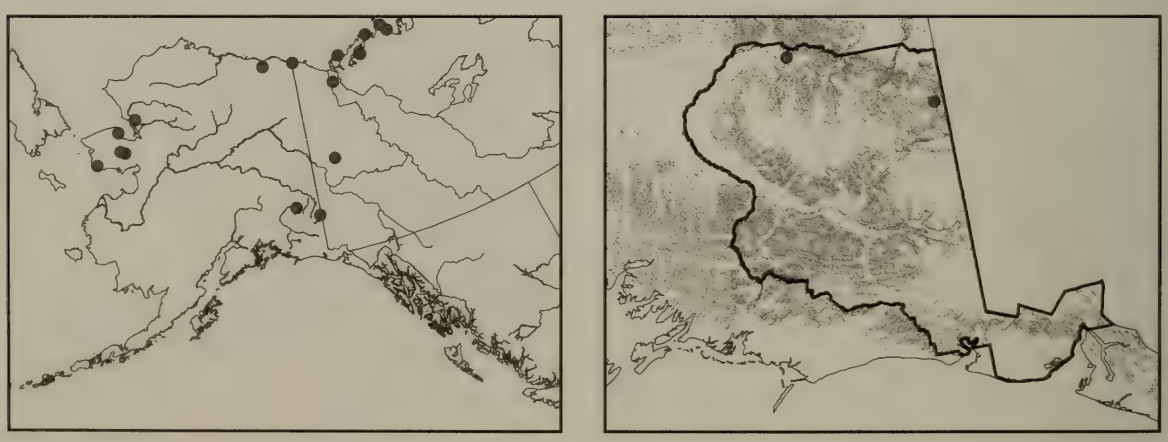
44. Carex crawfordii



45. *Carex eburnea*

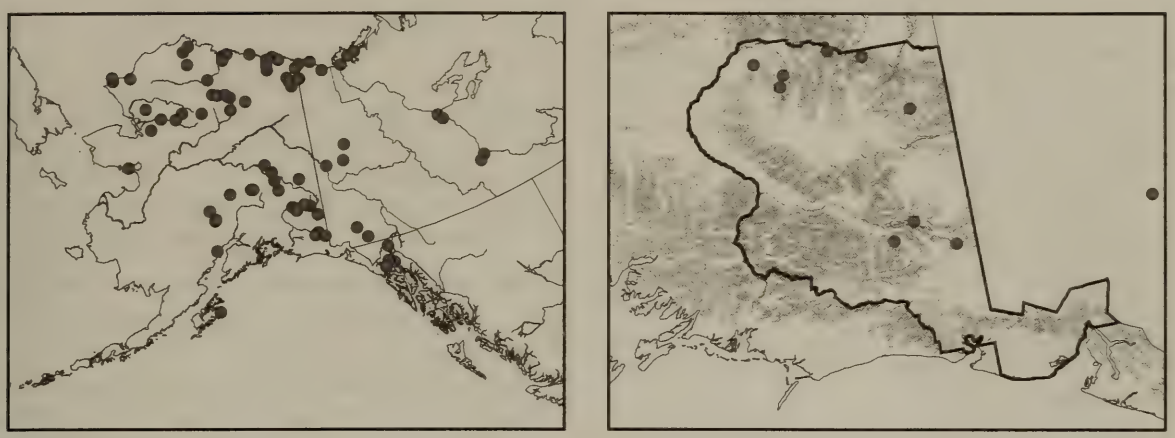


46. *Carex filifolia*

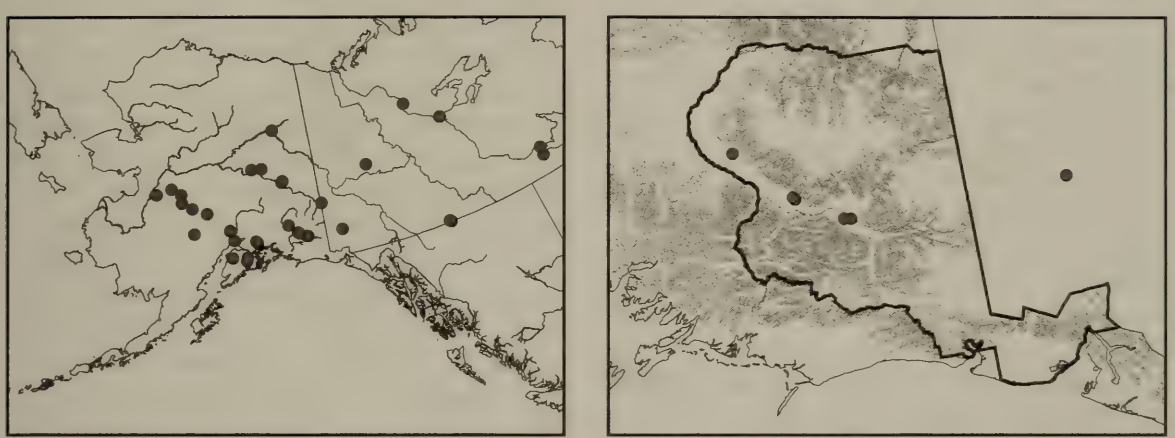


47. *Carex holostoma*

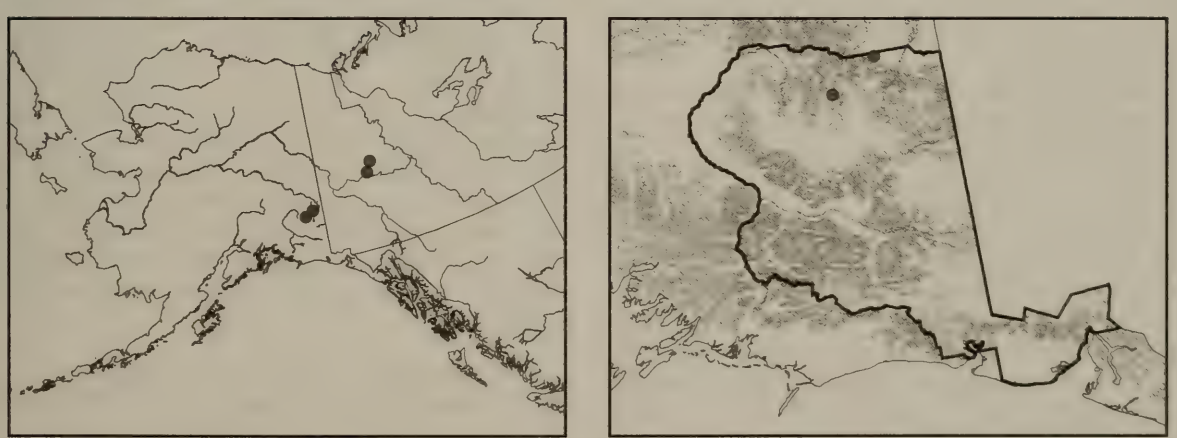
48. *Carex interior*



49. *Carex krausei*



50. *Carex lasiocarpa* ssp. *americana*



51. *Carex laxa*

52. *Carex lenticularis* var. *dolia*

62°19.02′ N 143°47.44′ W, *C. Roland 96-901*, 10 August 1996; patchy in mudflats between gravel bar and spruce woodland, Copper River at outflow creek from Lake 2990, 884 m, 62°24.38′ N 143°42.28′ W, *M. Cook 96724*, 8 August 1996.

This circumpolar arctic-alpine sedge had been collected at the head of the Chitna River (*H.M. Laing 21*, 1925 (CAN) (Hultén 1941-1950; Porsild 1939)). The collections cited above extend its range into the Wrangell, Mentasta and Nutzotin Mountains and connect the distribution 243 km to the north in the Alaska Range (Caster Glacier, 63°24.0′ N 145°43.0′ W, *Palmer & Porsild 467*, 27 June 1926 (ALA)). Map 49.

Carex lasiocarpa Ehrh. ssp. *americana* (Fern.) Hult., Wooly-Fruit Sedge — CHUGACH MOUNTAINS: river terraced wetlands surrounded by White Spruce forest, Tana River flats, 442 m, 61°14.45′ N 142°57.21′ W, *Duffy & Barnes 96-118*, *Parker & Gracz 6788*, 8 August 1996. WRANGELL MOUNTAINS: dense swards around small pond, Chokosna Lake, 619 m, 61°27.45′ N 143°49′ W, *C. Roland 94-330*, 10 August 1994; abundant in wet sedge meadow, vic. Dadina River, 744 m, 61°53.05′ N 144°44.09′ W, *C. Roland 96-339*, 2 July 1996; dominant in pond, Kuskulana River, 509 m, 61°28.53′ N 143°50.77′ W, *C. Roland 96-720, 96-723*, 26 July 1996.

This North American boreal-montane species is rare in the Yukon Territory (Douglas et al. 1981). The specimens cited above extend its range east 231 km into the Copper and Chitina River basins from a collection in the Anchorage Quad (Otter Lake, 61°17.53′ N 149°44.17′ W, *Duffy & Tande 1017*, 3 Aug 1994 (ALA)). Map 50.

Carex laxa Wahlenb., Weak Sedge — NUTZOTIN MOUNTAINS: scattered in marsh, Lick Creek, 914 m, 62°28.89′ N 142°7.56′ W, *Cook & Beck 95112A*, 29 June 1995. WRANGELL MOUNTAINS: graminoid meadow, confluence of Monte Cristo Creek and Nabesna River, 1067 m, 62°14.27′ N 142°55.81′ W, *C. Roland 96-134*, 18 June 1996.

The collections of this boreal-montane sedge cited above are the only verified stations in Alaska. David F. Murray reviewed the collection from Mile 172-174 on the Richardson Highway (*J. P. Anderson 2712B* (S), Hultén 1941-1950) but could not confirm the original determination from the material (personal communication with D. F. Murray, 11 July, 2000). The collections cited above extend its range 368 km to the west from the Yukon Territory. This sedge is rare in Alaska (G4 S1) and in the Yukon Territory (Douglas et al. 1981). Map 51.

Carex lenticularis Michx. var. *dolia* (M.E. Jones) L.A. Standley. comb. nov. (*C. enanderi* Hult.), Lakeshore Sedge — CHUGACH MOUNTAINS: flooded silt bar of tributary stream, Martin Creek, 1097 m, 60°56′ N 142°23′ W, *Batten & Barker 96-266*, 28 July 1996; scattered in snowmelt rivulet, west fork of 12-mile Creek, 1326 m, 60°50.21′ N 142°30.85′ W, *C. Roland 96-787*, 29 July 1996; marsh on alluvial fan, Granite Creek, 823 m, 60°44′ N 142°13′ W, *Batten & Barker 96-343*, 30 July 1996; moist meadow, west fork of 12-mile Creek, 1326 m, 60°50.21′ N 142°30.85′ W, *M. Cook 96593*, 7 July 1996 (ALA).

This North American cordilleran sedge is rare in Alaska (G5T3Q S3). The specimens cited above extend its range 188 km to the east of a collection in the Valdez Quad (Thompson Pass, 61°08.0′ N 145°45.0′ W, *C.L. Parker 2451*, 23 July 1990 (ALA)) and connect the range 423 km to the southeast near Skagway (Hultén 1968). Map 52.

Carex leptalea Wahlenb., Bristly-stalked Sedge — CHUGACH MOUNTAINS: sweetgale-graminoid bog, Tana River, 411 m, 61°12.59′ N 142°54.47′ W, *Duffy & Barnes 96-196*, 8 August 1996; scattered to common in small patch of wet sedge herb tundra, Tana River, 335 m, 61°11′ N 142°51′ W, *Parker & Gracz 6820*, 9 August 1996; common in elevated mossy hummocks in *Sphagnum* bog, Hanagita River, 762 m, 61°11.07′ N 143°25.81′ W, *Roland & D'Auria 96-493A*, 12 July 1996; common in elevated, somewhat drier margin of wet graminoid meadow, Nerelna Creek, 884 m, 61°25.3′ N 144°18.61′ W, *Roland & D'Auria 96-424*, 9 July 1996. GULF OF ALASKA BASIN: horsetail bog, Manby Beach, 59°47.52′ N 140°56.51′ W, *M. Cook 87-117*, 20 August 1987. NUTZOTIN MOUNTAINS: scattered in marsh, Lick Creek, 914 m, 62°28.89′ N 142°7.56′ W, *M. Cook 95113*, 29 June 1995. WRANGELL MOUNTAINS: clumped in *Sphagnum* at margin of pond, Lakina River, 792 m, 61°29.49′ N 143°25.6′ W, *M. Cook 96522*, 7 July 1996; elevated hummocks in wet sedge meadow, Dadina River, 744 m, 61°53.05′ N 144°44.09′ W, *C. Roland 96-341*, 2 July 1996.

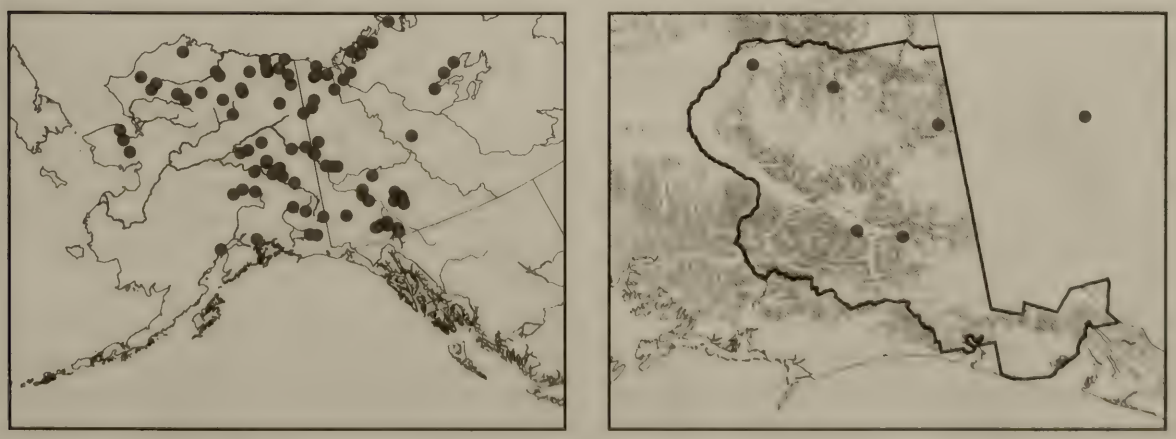
This sedge is North American with a boreal-montane distribution. The localities cited above extend its range south 220 km into the Nutzotin Mountains, 266 km into the Wrangell Mountains and 296 km into the Chugach Mountains from a station in the Alaska Range (Hultén 1968). The collection from the Malaspina Forelands extends the range 433 east of a station on the Kenai Peninsual (Hultén 1968). Map 53.

Carex nardina E. Fries, Nard Sedge — CHUGACH MOUNTAINS: rock outcrops, Chakina River, 1646 m, 61°5.31′ N 143°0.53′ W, *M. Cook 94213*, 8 July 1994; common in *Dryas*-sedge tundra, Juniper Island, 1291 m, 60°36.24′ N 142°21.69′ W, *M. Cook 94271*, 12 July 1994; SW-facing rock crevice, Juniper Island, 1346 m, 60°36.17′ N 142°14.96′ W, *Cook & Roland 94-205, 94250A*, 10 July 1994; occasional in marble rubble, Canyon Creek, 1463 m, 61°24.35′ N 144°20.8′ W, *Roland & D'Auria 96-437*, 9 July 1996. MENTASTA MOUNTAINS: scattered in tundra, Totschunda Creek, 1280 m, 62°27.63′ N 142°12.44′ W, *C. Roland 96-277*, 24 June 1996; dry tundra on S-facing slope, Devils's Mountain, 1530 m, 62°25.62′ N 142°53.93′ W, *C. Roland 96-360C*, 3 July 1996; common on limestone outcrops, Trail Creek, 1615 m, 62°36.05′ N 143°17.63′ W, *C. Roland 95-005*, 6 June 1995. NUTZOTIN MOUNTAINS: limestone gravel, Baultoff Creek, 1707 m, 62°9.13′

53. Carex leptalea

54. Carex nardina

55. Carex nigricans



56. Carex obtusata

N 141°14.51′ W, *C. Roland 94-164*, 28 June 1994; limestone ridge, Lime Butte, 1554 m, 61°21.56′ N 142°26.43′ W, *Cook & Roland 94-232B, 94298B*, 14 July 1994. ST. ELIAS MOUNTAINS: occasional on limestone gravel, Mt. Natazhat, 1716 m, 61°35.38′ N 141°1.83′ W, *M. Cook 95069*, 19 June 1995; common in disturbed marble rubble, Blondie Ridge, 1951 m, 60°53.94′ N 141°6.75′ W, *C. Roland 95-152*, 11 July 1995. WRANGELL MOUNTAINS: gravelly limestone, Chitistone Mountain, 1219 m, 61°28′ N 142°33' W, *Batten & Barker 96-141*, 26 July 1996; scattered in gravelly tundra, Cheshnina Plateau, 1399 m, 61°48.04′ N 144°6.27′ W, *C. Roland 96-854*, 6 August 1996.

This sedge is amphi-atlantic with an arctic-alpine distribution. It was collected in the Wrangell Mountains at Bonanza Ridge (Nordell and Schmitt 1978) and Guerin Glacier (61°37.0′ N 141°50.0′ W, *D.F. Murray 2066*, 3 August 1968 (ALA)). The localities cited above extend its range 118 km east from a station in the Alaska Range (Hultén 1968) and 102 km south into the Chugach Mountains from the Bonanza Ridge collection. Map 54.

Carex nigricans C.A. Mey, Blackish sedge — CHUGACH MOUNTAINS: alpine herbaceous meadow, Karr Hills, 549 m, 60°8.66′ N 141°16.44′ W, *K.A. Beck 87-11*, 12 August 1987; occasional in *Empetrum* heath, 12-mile Creek, 988 m, 60°50.51′ N 142°23.02′ W, *C. Roland 96-766A*, 29 July 1996; scattered in snowmelt rivulet, 12-mile Creek, 1326 m, 60°50.21′ N 142°30.85′ W, *C. Roland 96-788*, 29 July 1996; scattered in lush forb-herbaceous meadow, Granite River, 1344 m, 60°46.44′ N 142°5.12′ W, *C. Roland 96-800*, 29 July 1996; occasional in wet moss, vic. Spirit Mountain, 1006 m, 61°16.84′ N 144°29.86′ W, *M. Cook 96433*, 7 July 1996; occasional in *Cassiope/Luetkea* heath of alpine basin, vic. 12-mile Creek, 1271 m, 60°48.85′ N 142°33.52′ W, *M. Cook 96626*, 7 July 1996. GULF OF ALASKA: *Cassiope* alpine tundra, Samovar Hills, 549 m, 60°8.11′ N 140°39.55′ W, *M. Cook 87-102*, 23 August 1987; gravelly area next to wet equisetum meadow, Guyot Glacier, 183 m, 60°3.6′ N 141°18′ W, *K.A. Beck 92545*, 22 August 1992. WRANGELL MOUNTAINS: ridge 0.6 km S of Nadina Glacier, 1768 m, 62°2.85′ N 144°41′ W, *M. Cook 94424A*, 30 August 1994.

The northern limit of the range of this North American cordilleran sedge is documented by the collection cited above from the Wrangell Mountains. These collections extend its range 116 km to the northeast into the Wrangell Mountains, 203 km east into the Chugach Mountains and 291 km southeast into the southern St. Elias Mountains from a station near Thompson Pass (Hultén 1968) and connect the range 298 km to the southeast near Skagway (Hultén 1968). Map 55.

Carex obtusata Liljeb., Blunt Sedge — CHUGACH MOUNTAINS: rubbly area of SW-facing slope underlain by ultramafic rock, Chakina River, 1768 m, 61°6.19′ N 142°55.03′ W, *C. Roland 94-185B*, 8 July 1994; dry slopes, Goat Creek, 1487 m, 60°59.5′ N 142°1' W, *Batten & Barker 96-213*, 27 July 1996; dry soil on exposed bench, Goat Creek, 1487 m, 60°59.5′ N 142°1′ W, *Batten & Barker 96-316*, 29 July 1996 (ALA). NUTZOTIN MOUNTAINS: scattered in turfy, *Kobresia* dominated community on knoll, Rock Lake, 1119 m, 61°48.7′ N 141°16.57′ W, *C. Roland 96-033*, 5 June 1996. WRANGELL MOUNTAINS: *Dryas*/dwarf willow tundra community, Moose Point, 1052 m, 62°31.61′ N 144°12.38′ W, *C. Roland 94-021*, 7 June 1994; occasional on dry hillside, Nabesna River bluff, 1106 m, 62°15.05′ N 142°54.68′ W, *C. Roland 96-157*, 19 June 1996; few in bare mineral soil on well drained slope, Nabesna River bluff, 1106 m, 62°15.05′ N 142°54.68′ W, *M. Cook 96192*, 6 June 1996.

This species is amphiberingean with an arctic-alpine distribution. The specimens cited above extend its range south 169 km into the Wrangell Mountains, 244 km into the Nutoztin Mountains and 315 km into the Chugach Mountains from a collection in the Alaska Range (Mt. Hayes Quad: 63°43.0′ N 144°23.0′ W, *Batten & Juday 85-207*, 12 July 1985 (ALA)) and connect the range 126 km to the east in the Yukon Territory (Cody 1996). Map 56.

Carex parryana Dew., Parry's Sedge — ST. ELIAS MOUNTAINS: open low willow scrub, Clear Stream, terminus of Barnard Glacier, 488 m, 61°5.82′ N 141°57.92′ W, *Duffy & Barnes 96-012*, 8 August 1996.

This North American boreal-montane sedge is rare in Alaska (G4 S1). The specimen cited above extends the range in the Chugach Mountains 348 km to the east from a collection in the Anchorage Quad (Eklutna, 61°28.0′ N 149°22.0′ W, *Dutilly et al. 20709*, 7 July 1947 (ALA)) and is 162 km west of collections in the Yukon Territory (Cody 1996). Map 57.

Carex pauciflora Lightf., Star Sedge — CHUGACH MOUNTAINS: boggy area in open tall willow alder scrub, Falls Creek, 610 m, 61°10.58′ N 144°24.75′ W, *M. Duffy 91103*, 12 August 1991; ericaceous shrub bog, Middle Fork of the Bremner River, 869 m, 60°55.05′ N 143°43.86′ W, *Duffy & Barnes 96-093*, 8 August 1996. GULF OF ALASKA: ericaceous shrub/graminoid herbaceous bog, Robinson Mountains, 427 m, 60°4.8′ N 142°12.8′ W, *M. Duffy 9216*, 11 June 1992.

The collections cited above extend the range of this boreal-montane sedge east 111 km in the Chugach Mountains and 206 km into the Robinson Mountains from a station near Cordova (Orca, 60°39.83′ N 145°43.00′ W, *I.L. Norberg s.n.*, 28 August 1938 (S), Hultén 1941) and connect the range 227 km to the southeast near Yakutat (Lost River area, 59°28.0′ N 139°40.0′ W, *C. L. Parker 2611*, 24 June 1991 (ALA)). Map 58.

Carex petasata Dew., Liddon Sedge — CHUGACH MOUNTAINS: locally common in a dry meadow on lateral moraine, Granite Creek, 884 m, 60°44.63′ N 142°6.05′ W, *C. Roland 96-791*, 29 July 1996 (ALA).

57. Carex parryana

58. Carex pauciflora

59. Carex petasata

60. Carex petricosa

This North American cordilleran sedge is new to the flora of Alaska and considered rare (G5 S1). The collection cited above is 262 km west of stations in the southwest Yukon near Haines Junction (Cody 1996) and represents the western limit of its known range. Map 59.

Carex petricosa Dewey, Rockdwelling Sedge — CHUGACH MOUNTAINS: dry soil on steep SW-facing slope, Goat Creek, 1487 m, 60°59.5′ N 142°1′ W, *Batten & Barker 96-219*, 27 July 1996; occasional patches in gravel and finer scree, vic. Iron Creek, 1612 m, 61°1.49′ N 141°54.23′ W, *M. Cook 96580*, 7 July 1996. MENTASTA MOUNTAINS: densely vegetated shoulder amid extensive gravel chutes on SW-facing slope, Totschunda Creek, 1280 m, 62°27.63′ N 142°12.44′ W, *C. Roland 96-296*, 24 June 1996. NUTZOTIN MOUNTAINS: subalpine meadow at treeline, Carden Hills, 1311 m, 62°18.44′ N 141°11.55′ W, *C. Roland 94-135*, 25 June 1994. ST. ELIAS MOUNTAINS: common in dry tundra on limestone, ridge between Dan & Copper Creeks, 1554 m, 61°21.56′ N 142°26.43′ W, *C. Roland 94-231B*, 14 July 1994; occasional in well-drained areas on limestone, Mt. Natazhat, 1716 m, 61°35.38′ N 141°1.83′ W, *C. Roland 95-059, 95-061*, 19 June 1995; in limestone scree with stringers of *Dryas alaskensis,* Mt. Natazhat, 1716 m, 61°35.38′ N 141°1.83′ W, *M. Cook 95078A*, 21 June 1995. WRANGELL MOUNTAINS: occasional in open, subalpine White Spruce forest and meadows on W-facing slope of limestone knoll, Fish Creek, 1067 m, 62°16.92′ N 142°58.99′ W, *C. Roland 95-305*, 30 July 1995.

This North American cordilleran sedge had been collected in the St. Elias Mountains (Guerin Glacier, 61°37.42′ N 141°4.38′ W, *D. F. Murray 2063*, 3 August 1968 (ALA)). The collections cited above extend its range 91 km south into the Chugach Mountains, 111 km north into the Nutzotin Mountains and 126 km northwest into the Wrangell Mountains. These collections also connect the range 203 km to the northwest in the Alaska Range (Mile 238 Richardson Highway, 63°40.0′ N 145°52.0′ W, *Batten & Dawe 78-123*, 4 July 1978 (ALA)) with the range 134 km to the east in the Yukon Territory (Cody 1996). Map 60.

Carex phaeocephala Piper, Dunhead Sedge — CHUGACH MOUNTAINS: scattered in loose, shaly talus on S-facing slope, vic. 12-mile Creek, 1335 m, 60°49.71′ N 142°33.34′ W, *C. Roland 96-815*, 30 July 1996; tufted on slope of moraine in *Arctostaphylos uva-ursi* patches, Granite River, 884 m, 60°44.63′ N 142°6.05′ W, *M. Cook 96602*, 7 July 1996; mesic shrub birch-ericaceous, Granite Creek, near Ross Green Lake, 701 m, 60°43.83′ N 142°28.78′ W, *Duffy & Barnes 96-056, 96-057*, 8 August 1996.

This North American cordilleran sedge is rare in the Yukon Territory (Douglas et al. 1981) and known from only five localities in Alaska. The collections cited above extend its range 104 km east in the Chugach Moutains from a collection near Cordova (Schwan Glacier, 60°58.0′ N 145°00.0′ W, *C. Parker 1763,* 12 August 1986 (ALA)) and connect the range 134 km to the east in the Yukon Territory (Cody 1996). Map 61.

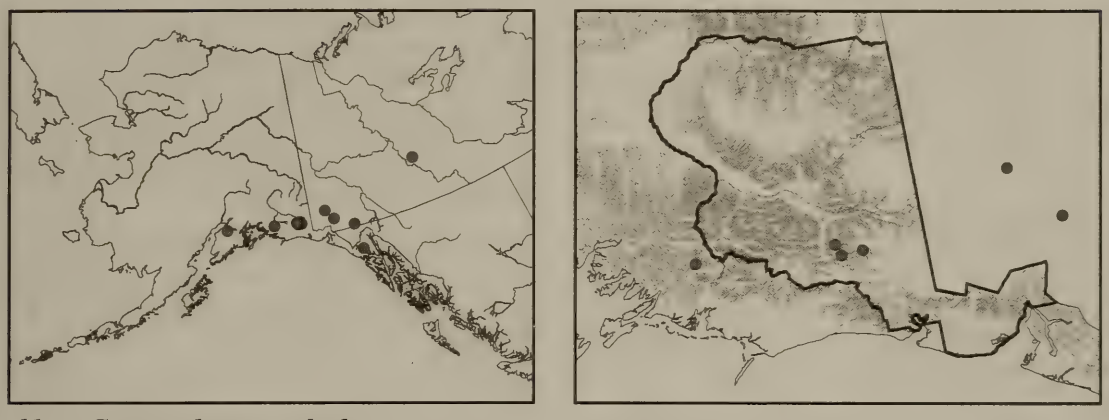
Carex praticola Rydb., Meadow Sedge — CHUGACH MOUNTAINS: silt of ledges, Juniper Island, 1346 m, 60°36.17′ N 142°14.96′ W, *Cook & Roland 94-204, 94254*, 10 July 1994; scree on S-facing boulder slope, Juniper Island, 1291 m, 60°36.24′ N 142°21.69′ W, *M. Cook 94260*, 11 July 1994; moist gravel, Short River Pond, 503 m, 61°5.35′ N 141°56.3′ W, *Parker & Duffy 6686*, 6 August 1996; edges of pools in marshy area, Granite River, 823 m, 60°44′ N 142°13′ W, *Batten & Barker 96-344*, 30 July 1996.

This sedge is North American with a boreal-montane distribution. The localites cited above extend its range 244 km east in the Chugach Mountains from a station near Valdez (Hultén 1968) and connect its range 283 km to the east in the Yukon Territory near Haines Junction (Cody 1996). Map 62.

Carex stylosa C.A. Mey, Variegated Sedge — CHUGACH MOUNTAINS: muddy margin of small kettle pond, Granite Creek, 701 m, 60°43.78′ N 142°31.4′ W, *Duffy & Barnes 96-066*, 8 August 1996; scattered in wet meadow, Granite River, 884 m, 60°44.63′ N 142°6.05′ W, *C. Roland 96-795B*, 29 July 1996; sedge meadow, Upper Tebay Lake, 579 m, 61°11.5′ N 144°23′ W, *L. A. & E. G. Viereck* 11096, 7 July 1996; mesic sedge herb meadow, Tebay Lake, 579 m, 61°11′ N 144°24′ W, *Parker & Gracz 6725, 6767A*, 7 August 1996; locally common in mossy heath, 12-Mile Basin, 1335 m, 60°49.71′ N 142°33.34′ W, *C. Roland 96-830*, 30 July 1996; ericaceous shrub bog, Middle Fork of the Bremner River, 869 m, 60°55.05′ N 143°43.86′ W, *Duffy & Barnes 96-091, 96-100*, 8 August 1996. WRANGELL MOUNTAINS: common in mud on tundra pond, Cheshnina Plateau, 1399 m, 61°48.04′ N 144°6.27′ W, *C. Roland 96-857*, 6 August 1996.

This amphiberingean boreal-montane sedge is rare in the Yukon Territory (Douglas et al. 1981). The collections cited above extend its range 135 northwest into the Wrangell Mountains and 214 east into the Chugach Mountains from a station near Worthington Glacier (61°1.08′ N 146°34′ W, *L.A. Viereck 8475*, 1 August 1967 (ALA)). Map 63.

Carex viridula Michx. (*C. oederi* Retz. ssp. *viridula* (Mischx.) Hult.), Little Green Sedge — CHUGACH MOUNTAINS: rare in wet silt on floodplain, confluence of Copper and Bremner Rivers, 152 m, 60°56.95′ N 144°41.79′ W, *C. Roland 96-610*, 17 July 1996. GULF OF ALASKA: wet sedge bog, Sudden Stream, 30 m, 59°30.71′ N 139°46.44′ W, *M. Cook 8850*, 20 July 1992; gravelly area next to wet *Equisetum* meadow, Guyot Glacier, 183 m, 60°3.6′ N 141°18′ W, *M. Cook 92552*, 19 August 1992. ST. ELIAS MOUNTAINS: wet fen in black spruce woodland, Bryson Bar, 1800 m, 61°4.57′ N 141°54.47′ W, *M. Duffy 91029*, 3 July 1991; mixed



61. Carex phaeocephala

62. Carex praticola

63. Carex stylosa

64. Carex viridula

graminoid-forb meadow, Clear Stream, 488 m, 61°5.82′ N 141°57.92′ W, *Duffy & Barnes 96-034*, 8 August 1996. WRANGELL MOUNTAINS: mud flats around Lake 2870, vic. Tanada Creek, 875 m, 62°31.38′ N 143°28.12′ W, *Moran & Roland 95-08*, 28 June 1995.

This amphiberingean boreal-montane sedge is rare in the Yukon Territory (Douglas et al. 1981) and known from few localities in Alaska. The collections cited above extend its range 190 km south into the Wrangell Mountains from a station in the Alaska Range (Hultén 1968), 337 km east in the Chugach Range from a collection in the Anchorage Quad (Bulldog Road bogs, 61°13.10′ N 149°41.40′ W, *Duffy & Tande 1065*, 5 August 1994 (ALA)) and 103 km to the west on the Malaspina Forelands from a station at Yakutat (59°29.86′ N 139°45.60′ W, *Stair & Pennell s.n.*, 1945 (PH), Hultén 1941-1950, Stair and Pennell 1947). Map 64.

Carex williamsii Britt., Williams' Sedge — NUTZOTIN MOUNTAINS: wet sedge meadow tundra at margin of kettle lake, northwest of Beaver-Horsfeld Creek confluence, 1097 m, 62°1′ N 141°11′ W, *Parker & Gracz 6844*, 10 August 1996.

This amphiberingean arctic-alpine sedge is rare in the Yukon Territory (Douglas et al. 1981). The collection cited above extends its range 205 km southeast into the Nutzotin Mountains from a station in the Alaska Range (Hultén 1968) and connects the range 155 km to the east in the Yukon Territory (Cody 1996). Map 65.

Eriophorum callitrix Cham., Arctic Cotton-grass — CHUGACH MOUNTAINS: moist soil near edge of pond, Martin Creek, 1097 m, 60°56′ N 142°23′ W, *Batten & Barker 96-246* (ALA), *96-264*, 28 July 1996 (ALA). WRANGELL MOUNTAINS: Lakes Plateau, 1890 m, 62°4.4′ N 143°23.5′ W, *M. Potkin 95-100*, 30 July 1995; alpine basin, NW flank of Mt. Drum, 1615 m, 62°4.5′ N 144°45.91′ W, *C. Meyers 84-23*, 4 July 1984; scattered in wet graminoid meadow, Chetaslina Ridge, 1615 m, 61°56.51′ N 144°25.93′ W, *C. Roland 94-360*, 17 August 1994.

This circumpolar arctic-alpine grass was collected in the Wrangell Mountains at Chitistone Pass (Scott 1968). The localities cited above extend its range 151 km west into the western Wrangell Mountains and 87 km south into the Chugach Mountains. Map 66.

Eriophorum viridi-carinatum (Engelm.) Fern., Tassel Cotton-grass — WRANGELL MOUNTAINS: occasional in *Sphagnum* bog, Lakina River, Chitina River Basin, 792 m, 61°29.49′ N 143°25.6′ W, *C. Roland 96-672*, 24 July 1996.

This North American boreal-montane cotton-grass is rare in Alaska (G5 S2) and in the Yukon Territory (Douglas et al. 1981). The specimen cited above connects its distribution 259 km to the east in the Anchorage Quad (Muldoon bog, 61°12.22′ N 149°42.97′ W, *Duffy & Tande 923*, 26 July 1994 (ALA)) with a station 458 km to the southeast near Haines (Hultén 1968). Map 67.

Kobresia sibirica Turcz., Siberian Bog Sedge — NUTZOTIN MOUNTAINS: patchy on upper slope of S-facing bluff, White River, 1219 m, 61°44.3′ N 141°9.5′ W, *M. Cook 95085*, 21 June 1995.

This species is circumpolar with an arctic-alpine distribution. The specimen cited above extends its range 270 km to the southeast into the Nutzotin Mountains from a collection in the Alaska Range (Bear Creek, 63°37.0′ N 145°50.0′ W, *Batten & Dawe 78-42*, 29 June 1978 (ALA)) and connects the range 62 km to the east in the Yukon Territory (Cody 1996). Map 68.

Kobresia simpliciuscula (Wahlenb.) Mack., Simple Bog Sedge — MENTASTA MOUNTAINS: co-dominant in hummocky meadow on floodplain, Lost Creek, 1006 m, 62°32′ N 143°9.6′ W, *Roland & D'Auria 97-062, 97-073*, 26 June 1997. NUTZOTIN MOUNTAINS: mesic graminoid herbaceous meadow between Gold Run and Glacier Creeks, 1493 m, 62°7.42′ N 141°52.73′ W, *M. Cook 8983*, 23 July 1989; wet sedge meadow tundra at margin of kettle lake, Beaver-Horsfeld Creek confluence, 1097 m, 62°1′ N 141°11′ W, *Parker & Gracz 6843, 6857, 6900*, 10 August 1996; sedge meadow, N of Francis Creek, 1234 m, 61°53.78′ N 141°8.81′ W, *M. Duffy 96-273*, 8 August 1996.

The collections cited above of this circumpolar arctic-alpine sedge extend its range 136 km south into the Mentasta Mountains and 244 southeast into the Nutzotin Mountains from the Alaska Range (Hultén 1968) and connect its distribution 130 km to the east in the Yukon Territory (Cody 1996). Map 69.

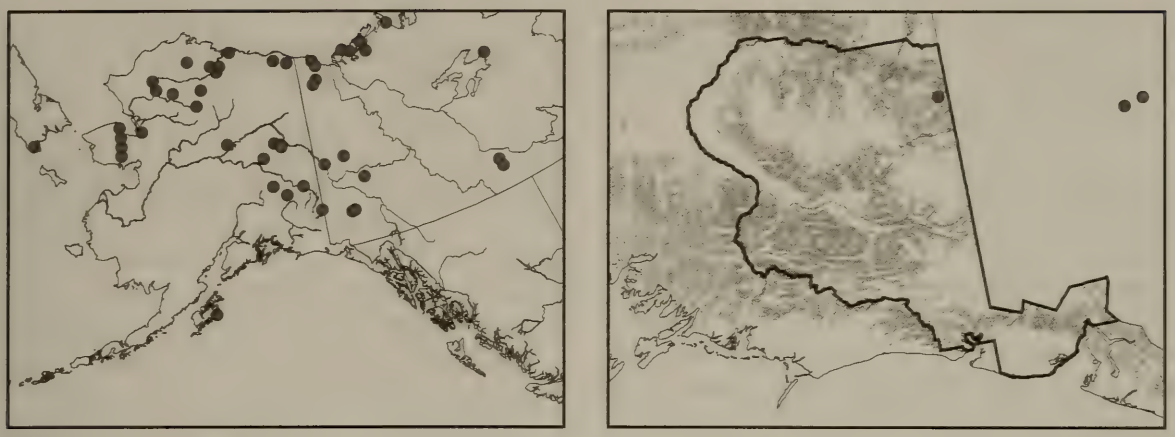
Trichophorum pumilum (M. Vahl.) Schinz. & Thell. var. *rollandii* (*Scirpus rollandii* Fern.), Rolland's Leafless-Bulrush — ST. ELIAS MOUNTAINS: wet alluvium at terminus of Barnard Glacier, St. Elias Mountains, 488 m, 61°5.82′ N 141°57.92′ W, *Duffy & Barnes 96-036*, 5 August 1996.

This boreal montane sedge is new to the state of Alaska. The collection cited above represents the western limit of its range and is 191 km west of collections in the Yukon Territory (Cody 1996). It is rare in Alaska (G3T3T4? S1) and in the Yukon Territory (Douglas et al. 1981). Map 70.

JUNCACEAE

Juncus filiformis L., Thread Rush — CHUGACH MOUNTAINS: abundant in mud, Granite River, 884 m, 60°44.63′ N 142°6.05′ W, *C. Roland 96-790*, 29 July 1996; scattered at margin of subarctic lowland sedge wet meadow, upper Tebay Lake, 579 m, 61°11′ N 144°24′ W, *Parker & Gracz 6738*, 7 August 1996. ST. ELIAS MOUNTAINS: wet sedge herb meadow tundra, Short River, 503 m, 61°5.35′ N 141°56.3′ W, *Parker & Duffy 6681*, 6 August 1996. WRANGELL MOUNTAINS: scattered on sandy beaches and alluvial flats, Fox Farm Lake, 727 m, 62°19.98′ N 144°50.02′ W, *C. Roland 95-260*, 25 July 1995; occasional in bare clay soil in graminoid meadow, SE end Boulder Lake, 1036 m, 62°31.27′ N 144°11.26′ W, *M. Cook 95365*, 2 August 1995; common along lake shore in open silt, Copper River, 911 m, 62°24.53′ N 143°42.68′ W, *C. Roland 96-917*, 11 August 1996.

This rush is circumpolar with a boreal-montane distribution. The collections cited above extend its range southeast



65. Carex williamsii

66. Eriophorum callitrix

67. Eriophorum viridi-carinatum

68. Kobresia sibirica

103 km into the Wrangell Mountains and 330 km into the Chugach Mountains from a station in the Alaska Range (Mile 3.3 Denali Highway, 63°40.0′ N 145°33.0′ W, *L.A. Viereck 8359*, 26 July 1967 (ALA)). Map 71.

Juncus mertensianus Bong., Merten's Rush — CHUGACH MOUNTAINS: rocks and saturated silt, lower Bremner River, 488 m, 61°0.81′ N 144°14.39′ W, *C. Meyers 84-104*, 20 July 1984; sand in open willow scrub, Granite River, 884 m, 60°44.32′ N 142°4.06′ W, *M. Cook 96616*, 7 July 1996; scattered forbs, Short River, 503 m, 61°5.35' N 141°56.3' W, *Parker & Duffy 6691*, 6 August 1996; scattered in moss, 12-Mile Basin, 1326 m, 60°50.21′ N 142°30.85′ W, *M. Cook 96599*, 7 July 1996; along stream in forb herbaceous vegetation, Falls Creek, 655 m, 61°14.17′ N 144°28.24′ W, *L. A. & E. G. Viereck 11044*, 7 July 1996; tall willow scrub, Granitic Creek, 1188 m, 61°4.37′ N 142°56.79′ W, *M. Hoffman s.n.*, 11 August 1986; in floating peat on lakeshore, Martin Creek, 1097 m, 60°56′ N 142°23′ W, *Batten & Barker 96-257*, 28 July 1996; abundant in meadow, Canyon Creek, 1035 m, 61°20.17′ N 144°19.38′ W, *C. Roland 96-549*, 15 July 1996; common in heath, 12-mile Creek, 988 m, 60°50.51′ N 142°23.02′ W, *C. Roland 96-765*, 7 July 1996; seepage area at margin of subarctic lowland sedge wet meadow, Granite Creek, 701 m, 60°43.81′ N 142°30.08′ W, *Parker & Gracz 6773*, 8 August 1996. ST. ELIAS MOUNTAINS: herbaceous meadow, Karr Hills, 60°8.66′ N 141°16.44′ W, *K. Beck s.n.*, 12 August 1987. WRANGELL MOUNTAINS: patchy in wet mud, Grant Creek, 853 m, 61°18.16′ N 143°51.87′ W, *Cook & Losso 96334*, 7 July 1996; moist fine sand along rivulet, Skolai Creek, 1341 m, 61°41.5′ N 142°23′ W, *Batten & Barker 96-129*, 25 July 1996; patchy in graminoid-forb meadow, Cheshnina Plateau, 1399 m, 61°48.04′ N 144°6.27′ W, *C. Roland 96-869*, 7 August 1996.

This rush is North American with a cordilleran distribution. The specimens cited above extend its range east 225 km into the Chugach Mountain, 285 km into the southern St. Elias Mountains and northeast 211 km into the Wrangell Mountains from a collection in the Valdez Quad (61°12.0′ N 145°47.0′ W, *L.A. Viereck 8472*, 1 August 1967 (ALA)). These localities also connect the range 151 km to the east in the Yukon Territory (Cody 1996). Map 72.

LILIACEAE

Maianthemum stellatum (L.) Link., Star-flowered Solomon's Seal — NUTZOTIN MOUNTAINS: *Populus balsamifera* forest on steep slope, between Sheep and Notch Creeks, 488 m, 62°15.09′ N 141°59.17′ W, *D. Morrison 84-41*, 19 June 1984.

This lily is North American with a boreal-montane distribution and is rare in Alaska (G5 S2). The specimen cited above extends its range 328 km to the east into the Nutzotin Mountains from a collection in the Anchorage Quad (Long Lake, 61°48.55′ N 148°14.56′ W, *M. Cook 3114*, 2 June 1998 (ALA)) and 292 km south from collections in the Eagle Quad (Mission Creek, 64°48.0′ N 141°10.0′ W, *Khokhryakov et al. 6294*, 10 July 1981 (ALA)). This locality also connects the distribution 170 km to the east in the Yukon Territory (Cody 1996). Map 73.

SALICACEAE

Salix commutata Bebb, Undergreen Willow — CHUGACH MOUNTAINS: flooded gravel bar, Martin Creek, 1097 m, 60°56′ N 142°23′ W, *Batten & Barker 96-262*, 28 July 1996; scattered in wet silt with *Equisetum*, Copper/Bremner River confluence, 152 m, 60°56.95′ N 144°41.79' W, *C. Roland 96-605*, 17 July 1996. GULF OF ALASKA BASIN: graminoid herbaceous meadow, Alder Stream, 59°44.22′ N 140°22.95′ W, *M. Cook 87-94*, 16 August 1987; horsetail bog, Cape Sitkagi, 61 m, 59°47.52′ N 140°56.51′ W, *M. Cook 87-99*, 20 August 1987; wet sedge marsh, Esker Stream, 59°54.19′ N 139°46.27′ W, *K. Beck s.n.*, August 1987.

The specimens cited above of this North American cordilleran willow extend its range 148 km to the east into the Chugach Mountains from a station on the Copper River near the Bremner River (Hultén 1968) and connect the range 90 km to the southeast near Yakutat (Harlequin Lake, 59°24.0′ N 139°00.0′ W, *L.A. Viereck s.n.*, 7 July 1965 (ALA)). Map 74.

Salix rotundifolia Trautv. ssp. *dodgeana* Rydb. — MENTASTA MOUNTAINS: limestone scree, Soda Lake, 1173 m, 62°32.36′ N 142°53.98′ W, *C. Roland 94-251*, 21 July 1994; common in rock crevices and stony tundra, Trail Creek, 1615 m, 62°36.05′ N 143°17.63′ W, *C. Roland 95-018*, 7 June 1995; common in calcareous gravel, Totschunda Creek, 1280 m, 62°27.63′ N 142°12.44′ W, *C. Roland 96-290*, 24 June 1996. NUTZOTIN MOUNTAINS: limestone gravels, Baultoff Creek, 1707 m, 62°9.13′ N 141°14.51′ W, *C. Roland 94-169*, *M. Cook 94187*, 28 June 1994. WRANGELL MOUNTAINS: blocky stone slope, Devil's Mountain, 1829 m, 62°27.97′ N 142°54.97′ W, *M. Duffy 91098*, 30 July 1991; alpine tundra, Nabesna Glacier moraine, 1798 m, 61°56.6′ N 143° W, *M. Duffy 92116*, 26 June 1992; scree slope, ridge S of Solo Flats, 1935 m, 61°28.41′ N 141°30.7′ W, *M. Duffy 92177*, 8 July 1992; talus slope, Lime Creek ridge, 1646 m, 61°46.25′ N 141°50.36′ W, *M. Cook 94110A*, 21 June 1994; rubble slope, NE slopes of Devil's Mountain, 1530 m, 62°25.62′ N 142°53.93′ W, *C. Roland 96-357*, 3 July 1996.

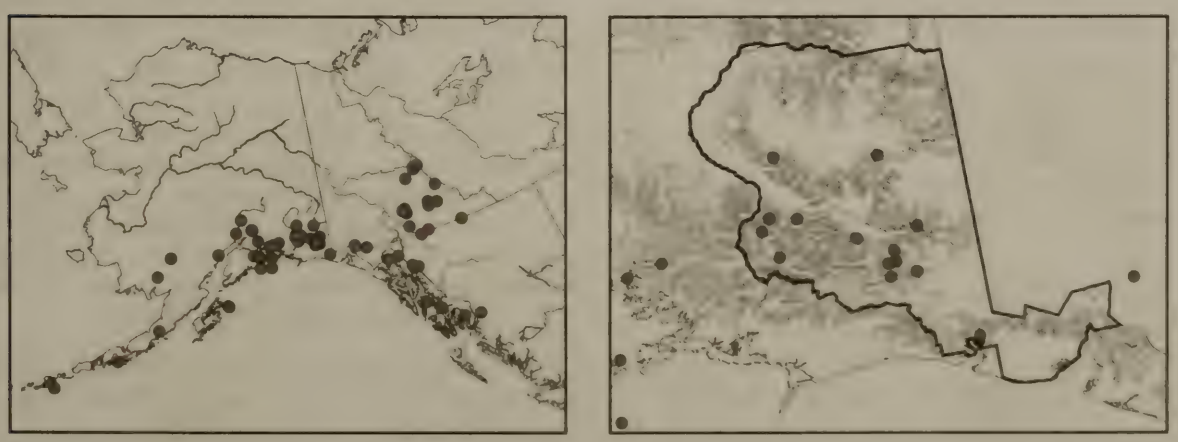
This willow is North American with a cordilleran distribution. The specimens cited above extend its range 193 km southeast into the Wrangell Mountains from a station in the Alaska Range (Argus 2000) with intermediary stations in the Mentasta and Nutzotin Mountains. Map 75.

Salix setchelliana Ball, Setchell's Willow — CHUGACH MOUNTAINS: rare in wet silt on floodplain, Bremner River, 152 m, 60°56.95′ N 144°41.79′ W, *C. Roland 96-611*, 17 July 1996; dunes at mouth of Bremner River, 69 m, 60°59.67′ N 144°34.63′ W, *L. A. & E. G. Viereck 11050*, 7 July 1996. MENTASTA MOUNTAINS: common in sandy areas of gravel bar, Totschunda Creek, 725 m, 62°26.94′ N 42°40.8′ W,

69. Kobresia simpliciuscula

70. Trichophorum pumilum var. *rollandii*

71. Juncus filiformis



72. Juncus mertensianus

C. Roland 96-252, *M. Cook 96250*, 23 June 1996. WRANGELL MOUNTAINS: scattered on sandy river bar, Bond Creek, 783 m, 62°19.42′ N 142°51.82′ W, *C. Roland 96-176*, 19 June 1996; scattered on stabilized river terrace, confluence of Jacksina and Nabesna Rivers, 759 m, 62°21.51′ N 142°52.87′ W, *C. Roland 96-198*, *M. Cook 96222*, 21 June 1996.

This Alaksa-Yukon endemic willow was collected at the head of the Chitina River (*H.M. Laing 224, 1925, 224* (CAN) (Porsild 1939; Hultén 1941-1950)) and is rare in Alaska (G3G4 S3) and in the Yukon Territory (Douglas et al. 1981). The new localities cited above extend its range 183 km west into the Chugach Mountains and 184 km northwest into the Mentasta Mountains. These stations connect its range 198 km to the west in the Anchorage Quad (Matanuska, 61°32.0′ N 149°14.0′ W, *J.P. Anderson 884*, 10 July 1931 (ALA)) and 139 km to the north on the Delta River (63°33.0′ N 145°50.0′ W, *G.W. Argus 13398*, 15 August 1989 (ALA)) with its range 92 km to the east in the Yukon Territory (Cody 1996). Map 76.

Salix stolonifera Cov., Stoloniferous Willow — ST. ELIAS MOUNTAINS: moist gravels, Short River, 503 m, 61°5.35′ N 141°56.3′ W, *Parker & Duffy 6684*, 6 August 1996.

This willow is endemic to Alaska and British Columbia and has a Pacific Coastal distribution. The specimen cited above extends its range 200 km northeast into the Chitina River basin from collections near Cordova (Argus 2000) and connects the range 229 km to the southeast at Cordova (Argus 2000). Map 77.

POLYGONACEAE

Rumex acetosa L. ssp. *alpestris* (Scop.) Love, Garden Sorrel — NUTZOTIN MOUNTAINS: dry, open shale surrounded by birch/willow shrub tundra, vic. Wiki Peak, 1433 m, 61°53.9′ N 141°9.51′ W, *C. Roland 94-114*, 22 June 1994; several patches in bare mineral soil surrounded by *Dryas* moss tundra, Horsfeld Creek, 1768 m, 62°2.88′ N 141°13.18′ W, *M. Cook 94162*, 24 June 1994; several large populations on SW-facing scree slope, Horsfeld Creek, 1768 m, 62°2.88′ N 141°13.18′ W, *C. Roland 94-129A*, 24 June 1994; few in moist fine mud of exposed lake shore, Braye Lakes, 1097 m, 62°3′ N 141°6′ W, *Parker & Gracz 6865*, 11 August 1996; few in sagebrush-grass vegetation on bluffs of old river terraces above Beaver Creek, 1097 m, 62°1′ N 141°11′ W, *Parker & Gracz 6897*, 12 August 1996.

This cordilleran species is rare in the Yukon Territory (Douglas et al. 1981). The collections cited above extend its range 607 km east from Lake Clark (Trail Creek, 60°50.0′ N 153°49.0′ W, *P. Caswell 96257*, 21 July 1996 (ALA)) and connect the distribution 151 km to the east in the Yukon Territory (Cody 1996). Map 78.

Rumex beringensis Yurtsev & Petrovsky (*R. graminifolius* DC), Bering Sea Dock — ST. ELIAS MOUNTAINS: scattered in volcanic ash deposit, Cub Creek, 1280 m, 61°37.27′ N 141°9.75′ W, *M. Cook 94182A*, 28 June 1994; occasional in bare soil on knoll in dry tundra, Mt. Natazhat, 1716 m, 61°35.38′ N 141°1.83′ W, *C. Roland 95-065*, 19 June 1995. WRANGELL MOUNTAINS: bare area under boulder, West Glacier, 1524 m, 62°18.31′ N 143°52.37′ W, *M. Duffy 92021*, 23 June 1991, *M. Duffy 92267*, 9 September 1992; patchy on S-facing scree slope, NE slope of Mt. Drum, 1433 m, 62°8.83′ N 144°30.18′ W, *M. Cook 94058*, *C. Roland 94-075*, 11 June 1994; rare on alluvium below cinder cone, north slope of Mt. Sanford, 1722 m, 62°23.4′ N 144°15.9′ W, *C. Roland 94-009*, 6 June 1994; scattered in bare sandy mineral soil, Chetaslina plateau, 1615 m, 61°56.51′ N 144°25.93′ W, *C. Roland 94-343*, 15 August 1994; *M. Cook 94479*, 16 August 1994; occasional in moist bare soil of solifluction lobes, Black Mountain, 1481 m, 62°20.85′ N 143°44.9′ W, *Cook & Beck 95140*, 7 July 1995; abundant in slumping lobes of organic-rich soil around rodent dens, volcanic ridge 6.4 km east of Snyder Peak, 1524 m, 62°4.47′ N 144°30.51′ W, *C. Roland 96-379*, 5 July 1996; scattered throughout alpine basin, upper Dadina River, 1344 m, 62°3.95′ N 144°25.18′ W, *M. Cook 96267*, 7 July 1996; scattered in moist gravel of alpine lake shore, between Klawasi and Nadina Rivers, 1042 m, 62°1.95′ N 144°52.49′ W, *M. Cook 96273*, 7 July 1996; patchy in bare sandy areas along edge of cliff, Cheshnina Plateau, 1399 m, 61°48.04′ N 144°6.27′ W, *C. Roland 96-850*, 6 August 1996; *M. Cook 96700*, 8 August 1996.

This amphiberingain species with a Pacific coastal distribution, is rare in Alaska (G3 S3). It had been collected by David F. Murray at Sheep and Guerin Glaciers in the St. Elias Mountains (Murray 1971). The specimens cited above extend its range 201 km into the western Wrangell Mountains. These collections document the eastern limit of its range and are disjunct from the closest locality 507 km to the southwest at Lake Clark (Tanalian Point, 60°12.0′ N 154°19.0′ W, *D.R. Hunt 44*, 11 June 1993 (ALA)). Map 79.

PORTULACACEAE

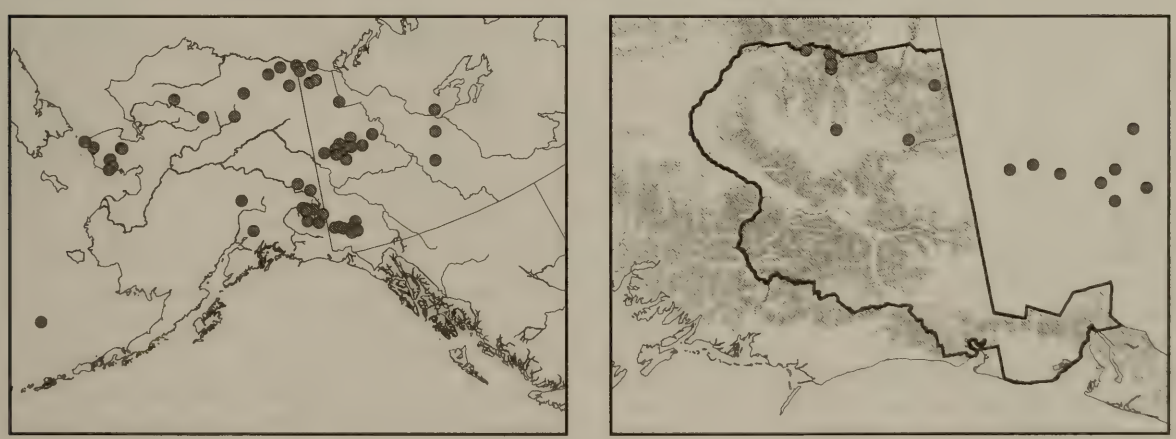
Claytonia tuberosa Pall., Tuberous Springbeauty — NUTZOTIN MOUNTAINS: open area within closed low birch scrub, vic. Rock Lake, 1113 m, 61°49.6′ N 141°20′ W, *M. Duffy 91090*, 22 July 1991; rare in subalpine meadow within open spruce forest, Carden Hills, 1311 m, 62°18.44′ N 141°11.55′ W, *C. Roland 94-134A*, 25 June 1994; scattered in bare, wet ash deposit, Flat Lake, 1323 m, 61°58.97′ N 141°41.25′ W, *C. Roland 95-046*, 17 June 1995; scattered in wetlands along Carl Creek, 1402 m, 62°2.81′ N 141°34.65′ W, *M. Cook 3153*, 2 July 1998.

This species is amphiberingian with a boreal-montane distribution. The collections cited above extend its range 158 km south into the Nutzotin Mountains from a collection in the Tanacross Quad (Mt. Fairplay, 63°40.0′ N 142°13.0′ W, *G. Smith 2426*, 30 June 1954 (ALA)) and connect the range 140 km east in the St. Elias Mountains of the Yukon Territory (Cody 1996). Map 80.

Montia bostockii (A.E. Porsild) Welsh (*Claytonia bostockii* Pors.), Bostock's Minerslettuce — CHUGACH MOUNTAINS: sedge-*Dryas* tundra, Virgin Gulch, 1539 m, 61°15.52′ N 142°31.09′ W, *M. Protti*

73. Maianthemum stellatum

74. Salix commutata



75. Salix rotundifolia ssp. *dodgeana*

76. Salix setchelliana

9104, 17 July 1991. MENTASTA MOUNTAINS: numerous in moist sedge/birch meadow, Big Grayling Lake, 1036 m, 62°32.93′ N 143°143.08′ W, *G. Dodge s.n.* June 1993; scattered in mesic *Dryas* tundra, ridge E of Soda Lake, 1173 m, 62°32.36′ N 142°53.98′ W, *M. Cook 94307*, 21 July 1994; occasional in open *Picea mariana* muskeg, Lost Creek floodplain, 1006 m, 62°32′ N 143°9.6′ W, *Roland & D'Auria 97-074*, 26 June 1997. NUTZOTIN MOUNTAINS: open shrub thicket, confluence of Notch Creek and Chisana River, 1097 m, 62°10.5′ N 142°5.5′ W, *J. Bolivar 84-48*, 25 June 1984; moist sedge meadow, Solo Flats, 1402 m, 61°50.67′ N 141°47.05′ W, *M. Duffy 92153*, 7 July 1992; rare in low areas between dunes, Beaver Lake, 1341 m, 62°2.61′ N 141°48.39′ W, *M. Cook 94198*, 29 June 1994; scattered in moss along stream bank, volcanic plateau between Bryan and Willow Creeks, 1829 m, 61°58.97′ N 141°50.03′ W, *M. Cook 95055B*, 18 June 1995; few in saturated moss, Braye Lakes, 1097 m, 62°2′ N 141°9′ W, *Parker & Gracz 6870*, 11 August 1996; saturated moss, open birch-willow scrub, Ptarmigan Lake, 1097 m, 61°50.03′ N 141°13.75′ W, *Duffy & Barnes 96-211*, 8 August 1996. ST. ELIAS MOUNTAINS: open tundra muskeg, McColl Ridge, 1341 m, 61°12.36′ N 142°39.64′ W, *J. Bolivar 84-106*, 15 July 1984. WRANGELL MOUNTAINS: tussock muskeg ridgetop, between Grizzly Lake and Jacksina Creek, 1890 m, 62°14.51′ N 143°17.46′ W, *J. Bolivar 84-115*, 23 July 1984; *Dryas*-sedge tundra, NW slope of Mt. Sanford, 1296 m, 62°21.17′ N 144°24.52′ W, *M. Cook 93125*, 9 June 1993; Lakes Plateau, 1890 m, 62°4.4′ N 143°23.5′ W, *M. Potkin 95-067*, 28 July 1995; occasional in wet swale, bench between Monte Cristo Creek and Nabesna River, 1021 m, 62°14.07′ N 142°56.85′ W, *C. Roland 96-139*, 18 June 1996.

This arctic-alpine Alaska-Yukon endemic was collected by D. F. Murray and R. W. Scott at Chitistone Pass in the Wrangell Mountains (Murray 1968, Scott 1968). The specimens cited above extend its range 152 km west into the Wrangell Mountains, 61 km south into the St. Elias Mountains, 114 km northwest into the Mentasta Mountains and 62 km north into the Nutzotin Mountains. The closest localities are 77 km to the north in the Nabesna Quad (Tetlin Mountains, 62°41.0′ N 142°46.0′ W, *K. Teare 1610*, 14 July 1983 (ALA)) and 58 km to the east in the Yukon Territory (Cody 1996). It is rare in Alaska (G3 S3) and in the Yukon Territory (Douglas et al. 1981). Map 81.

CARYOPHYLLACEAE

Arenaria capillaris Poir., Beautiful Sandwort — CHUGACH MOUNTAINS: talus slope and *Dryas* tundra, Hundell Creek, 1615 m, 61°36.75′ N 144°42.2′ W, *M. Cook 93465*, 28 August 1993; dry S-facing slope, Towhead Mountain, 1433 m, 61°3.21′ N 142°39.8′ W, *Duffy & Barnes 96-176*, 8 August 1996; *Dryas*-lichen tundra, Five-Mile Creek, 1219 m, 61° 32.29′N 144 33.11′W, *M. Cook 3539*, 15 July 2000.

This amphiberingian cordilleran species, rare in the Yukon Territory, was collected in the vicinity of the Park by J.P. Anderson along the Slana-Tok Highway in 1935 (Hultén 1940-1951), Charles W.H. Heidemann in 1908 near Copper Center (Hultén 1940-1951) and at Tazlina Glacier (61°45.0′ N 146°30.0′ W, *L. A. & E.G. Viereck 2191*, 19 July 1957 (ALA)). The specimens cited above extend its range 111 km east in the Chugach Mountains. Map 82.

Arenaria longipedunculata Hult., Longstem Sandwort — ST. ELIAS MOUNTAINS: wet alluvium of gravel bar, Barnard Glacier terminus, Chitina River, 488 m, 61°5.82′ N 141°57.92′ W, *Duffy & Barnes 96-028*, 8 August 1996.

This North American cordilleran species is rare in Alaska (G3G4Q S3) and of limited distribution in the Yukon Territory (Cody 1996). The specimen cited above extends its range 536 km southeast into the St. Elias Mountains from a locality near Healy (*A.E. Porsild 339*, 1926 (CAN), Hultén 1941-1950) and connects the distribution 212 km to the southwest in the Yukon Territory (Cody 1996). Map 83.

Cerastium regelii Ostenf., Regel's Chickweed — WRANGELL MOUNTAINS: mesic sedge grass meadow tundra, Lakes Plateau, 1890 m, 62°4.4′ N 143°23.5′ W, *Potkin & Leggett 95-085*, 29 July 1995 (ALA).

This species is circumpolar with an arctic-alpine distribution and is rare in Alaska (G4 S2S3). Our distribution map reflects the combination of *C. jenisejense* with *C. regelii* by Heide et. al. (1990). The specimen cited above is 1071 km to the east of a collection made by Eric Hultén at Cape Newenham in western Alaska and 417 km south of a station in the Steese-White Mountains (Hultén 1968). Map 84.

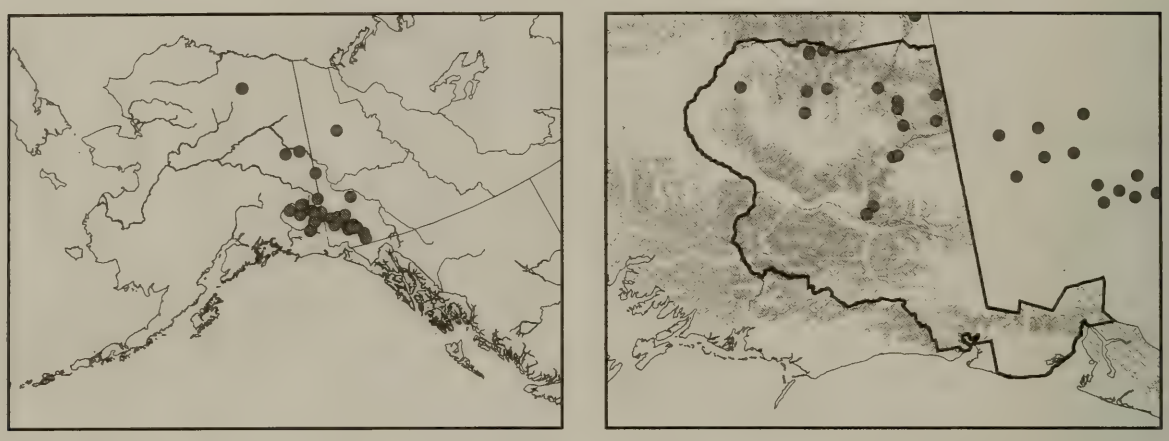
Minuartia biflora (L.) Schinzl. & Thell., Mountain Stitchwort — CHUGACH MOUNTAINS: moist bouldery solifluction lobe, East Fork Kiagna River, 1487 m, 60°59.5′ N 142°1′ W, *Batten & Barker 96-311*, 29 July 1996 (ALA); scattered in *Rhacomitrium* of dry tundra, Nerelna Creek plateau, 1372 m, 61°26.66′ N 144°17.69′ W, *M. Cook 96309*, *Roland & D'Auria 96-411*, 8 July 1996. MENTASTA MOUNTAINS: scattered in mesic dwarf willow-*Dryas*-moss community, Lost Creek, 1722 m, 62°36.45′ N 143°12.03′ W, *M. Cook 95169*, 7 July 1995. NUTZOTIN MOUNTAINS: occasional in bare organic soil between boulders at base of scree slope, 1585 m, 62°25.78′ N 142°22.11′ W, *M. Cook 95107*, 28 June 1995; moist sandy soil with seral herbs on well-vegetated SE-facing alpine colluvium, Horsfeld Creek, 1128 m, 62°2′ N 141°11′ W, *Parker & Gracz 6914*, 13 August 1996. ST. ELIAS MOUNTAINS: occasional in lush, steep, S-facing meadow, Mt. Natazhat, 1716 m, 61°35.38′ N 141°1.83′ W, *C. Roland 95-068*, 20 June 1995; few in bare organic soil on rock moraine, Mt. Chitina, 2073 m, 60°57.74′ N 141°17.33′ W, *M. Cook 95224*, *C. Roland 95-195*, 14 July 1995. WRANGELL MOUNTAINS: moist gravel, sparsely vegetated, SE slope of Fredrika Mountain, 1859 m, 61°43.8′ N 142°6.46′ W, *M. Duffy 91092*, 2 July 1991; rare in mesic stony area, Cone Ridge, 2073 m, 62°8.21′ N 143°18.47′ W, *C. Roland 94-299*, 25 July 1994; rare in mesic, mossy area of N-facing gravel slope,

77. *Salix stolonifera*

78. *Rumex acetosa* ssp. *alpestris*

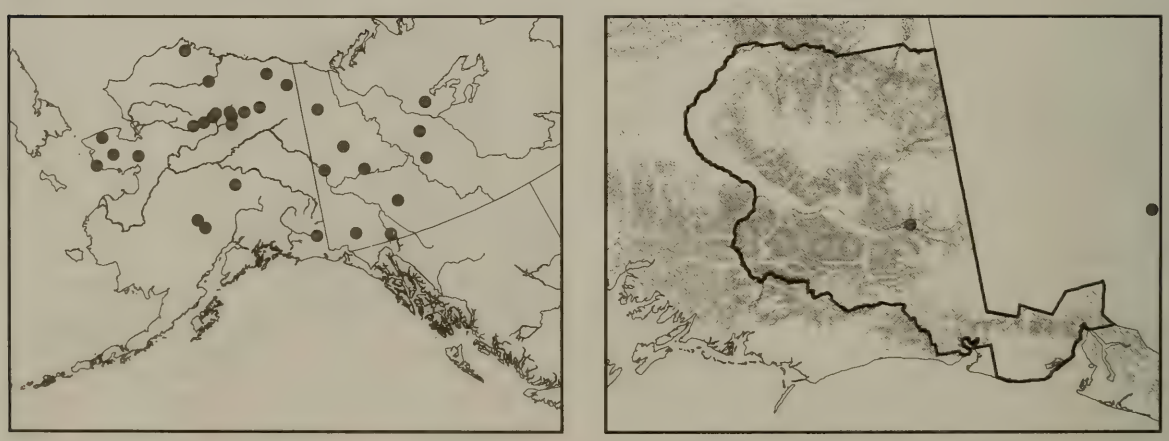
79. *Rumex beringensis*

80. *Claytonia tuberosa*



81. Montia bostockii

82. Arenaria capillaris

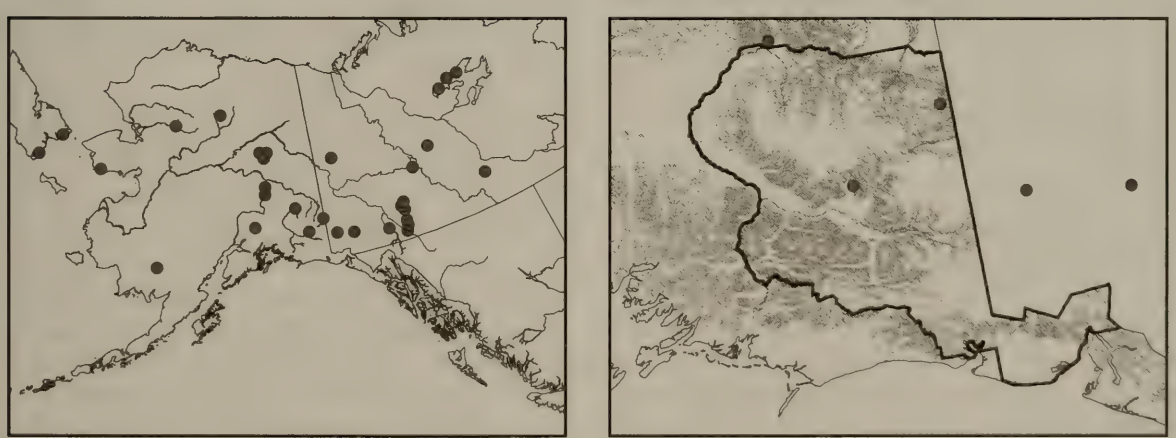


83. Arenaria longipedunculata

84. Cerastium regelii

85. Minuartia biflora

86. Minuartia dawsonensis



87. Minuartia stricta

88. Sagina saginoides

Crystalline Hills, 1585 m, 61°23.59′ N 143°31.85′ W, *C. Roland 95-249*, 18 July 1995; dry tundra on ridge Nikolai Pass, 1280 m, 61°26′ N 142°40′ W, *Batten & Barker 96-002*, 23 July 1996 (ALA); rare in mossy, stony saturated soil of seep, Hasen Creek, 1835 m, 61°34.06′ N 142°18.33′ W, *C. Roland 96-643*, 23 July 1996; scattered in sedimentary gravel scree on lower third of slope, West Fork Mill Creek, 1241 m, 61°33.33′ N 143°28.35′ W, *M. Cook 96519*, 24 July 1996; occasional in moss between gravel at base of slope, Lakina Glacier, 1219 m, 61°33.64′ N 143°19.01′ W, *M. Cook 96545*, 24 July 1996; moist muddy scree, Nikolai Mine, 1695 m, 61°27′ N 142°39′ W, *Batten & Barker 96-089B*, 24 July 1996 (ALA); moist gravelly clay, VABM Sentinel west of Nizina Glacier, 1829 m, 61°39′ N 142°32′ W, *Batten & Barker 96-110A*, 24 July 1996 (ALA); scree, ridge W of Nikolai Pass, 1372 m, 61°26.5′ N 142°43′ W, *Batten & Barker 96-161A*, 26 July 1996.

This circumpolar arctic-alpine species, which is rare in Alaska (G5 S2), was previously known from three localities in the Wrangell Mountains: Chitistone Pass (61°37′ N 142°3′ W, *R. Scott 1630, 1867, 2214* (MICH), Scott 1968), Skolai valley (61°37′ N 141°58′ W, *D. F. Murray 719* (CAN), Murray 1968) and Bonanza Ridge (61°30′ N 142°51′ W, *Nordell & Schmitt 95, 416b, 450,* (LD & ALA), Nordell and Schmitt 1968). The new collections cited above extend the range of this species 124 km north into the Mentasta Mountains, 64 km north into the Nutzotin Mountains, 123 km southwest into the Chugach Mountains, 75 km northwest in the Wrangell Mountains and 105 km southeast into the St. Elias Mountains. These collections join the range 152 km to the northeast in the Mt. Hayes Quad (Tangle Lakes, 63°03.0′ N 146°01.0′ W, *G. Smith 2033*, 20 August 1953 (ALA)) with the range 204 km to the east in the Yukon Territory (Cody 1996). Map 85.

Minuartia dawsonensis (Britt.) Mattf., Rock Stitchwort — CHUGACH MOUNTAINS: Copper River bluff below Gulkana airport, 457 m, 62°10.45′ N 145°24.3′ W, *D. Taylor 8536*, 11 July 1984. NUTZOTIN MOUNTAINS: Black Spruce woodland, Tanana River lowlands, 2900 m, 62°25.09′ N 141°34.33′ W, *M. Duffy 91010*, 19 June 1991; scattered on shore, Braye Lakes, 1097 m, 62°2′ N 141°9′ W, *Parker & Gracz 6883*, 11 August 1996. ST. ELIAS MOUNTAINS: shore of Mt. Chitina lake, 823 m, 60°57.74′ N 141°17.33′ W, *M. Cook 95260*, 17 July 1995. WRANGELL MOUNTAINS: spruce-aspen woodland, small patch on trail, 3 mi E of Strelna Creek, 619 m, 61°33.98′ N 144°1.56′ W, *M. Cook 3137*, 17 June 1998 (ALA); mixed woodland floodplain gravel bar, Kennicott River, 427 m, 61°26.38′ N 142°57.64′ W, *M. Cook 3515*, 30 September 1998 (ALA).

This species is North American with a boreal-montane distribution. The specimens cited above extend its range 160 km into the southern Wrangells, 160 km southeast into the Nutzotin Mountains and 237 km southeast into the St. Elias Mountains from a station near Mentasta Pass (Hultén 1968). These collections connect the distribution in the Alaska Range with the distribution 129 km to the east in the Yukon Territory (Cody 1996). Map 86.

Minuartia stricta (Sw.) Hiern, Rock Sandwort — NUTZOTIN MOUNTAINS: wet sedge meadow tundra at margin of kettle lake, vic. Horsfeld Creek, 1097 m, 62°1′ N 141°11′ W, *Parker & Gracz 6842*, 10 August 1996.

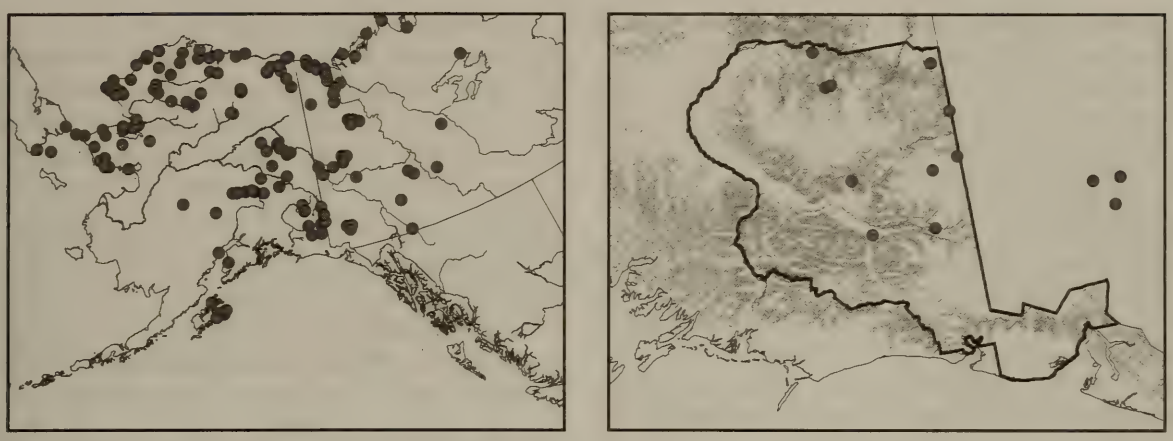
This circumpolar arctic-alpine species was known from Bonanza Ridge in the Wrangell Mountains (61°30′ N 142°51′ W, *Nordell & Schmitt 256, 463* (LD & ALA) (Nordell and Schmitt 1977)) and a station near Slana (Hultén 1968). The specimen cited above extends its range 104 km east into the Nutzotin Mountains. Map 87.

Sagina saginoides (L.) Karst., Arctic Pearlwort — CHUGACH MOUNTAINS: occasional in wet mud, Grant Creek, *Cook & Losso 96339*, 8 July 1996; shady steep bouldery soil, Goat Creek, 1487 m, 60°59.5′ N 142°1′ W, *Batten & Barker 96-312B*, 29 July 1996 (ALA); lush meadow, 12-Mile Basin, 1326 m, 60°50.21′ N 142°30.85′ W, *C. Roland 96-783*, 29 July 1996. COPPER RIVER BASIN: sandy riverbed, Gulkana Airport, 381 m, 62°10.5′ N 145°24.57′ W, *K. Teare 1658A*, 8 June 1984. GULF OF ALASKA BASIN: open willow scrub, 60°5.43′ N 141°25.51′ W, *M. Duffy 92255*, 22 August 1992. WRANGELL MOUNTAINS: small patches of fine soil surrounded by cobbles, Skolai Creek, 1341 m, 61°41.5′ N 142°23′ W, *Batten & Barker 96-125*, 25 July 1996 (ALA).

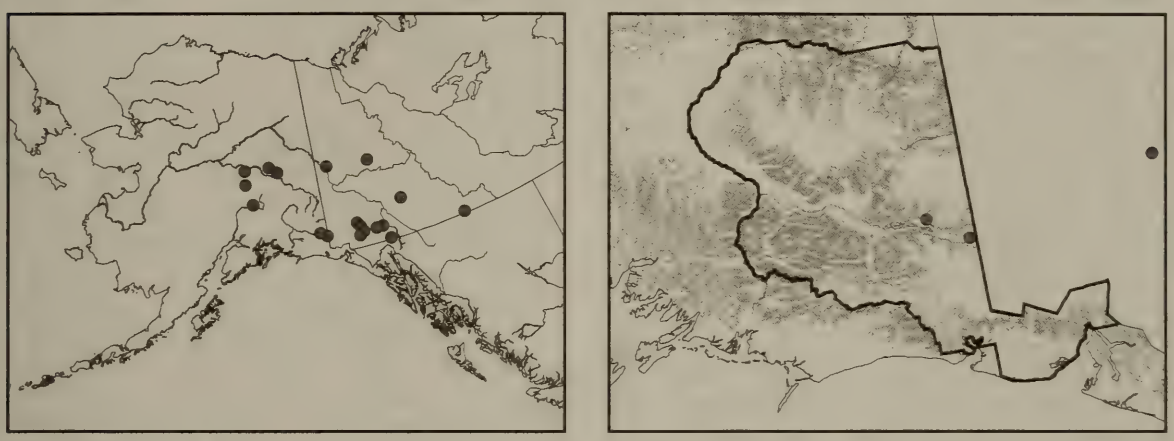
This species is circumpolar with a widespread distribution. The localities cited above extend its range 150 km east into the Wrangell Mountains, 168 km southeast into the Chugach Mountains and 268 km southeast into the southern St. Elias Mountains from stations near Copper Center and Willow Creek along the Richardson Highway (Hultén 1968). Map 88.

Silene involucrata (Cham. & Schlecht.) Bocquet ssp. *involucrata* (*Melandrium affine* J. Vahl), Arctic Catchfly — CHUGACH MOUNTAINS: rock outcrop, Towhead Mountain, 1433 m, 61°3.21′ N 142°39.8′ W, *Duffy & Barnes 96-154*, 8 August 1996. MENTASTA MOUNTAINS: rare in understory of dry *Populus balsamifera* forest on steep, S-facing slope, Lost Creek , 1097 m, 62°33.3′ N 143°9′ W, *Roland & D'Auria 97-035*, 26 June 1997. NUTZOTIN MOUNTAINS: S-facing scree and N-facing graminoid-forb tundra, vic. Ptarmigan Creek, 1494 m, 61°32.89′ N 141°3.28′ W, *M. Cook 92480*, 9 July 1992; rare in meadow tundra, Carden Hills, 1311 m, 62°18.44′ N 141°11.55′ W, *C. Roland 94-134B*, 25 June 1994; occasional on S-facing talus slope, Rocker Creek, 1433 m, 61°54.8′ N 141°2.03′ W, *Cook & Roland 94139*, 23 June 1994. WRANGELL MOUNTAINS: N-facing scree slope, ridge between Lime Creek and Solo Flats, 1707 m, 61°28.41′ N 141°29.44′ W, *M. Cook 92500, 92109*, 7 July 1992; Jaegar Mesa, 1893 m, 62°15.9′ N 143°1.24′ W, *Moran & Roland 95-39*, 1 July 1995; few on S-facing bluff, Ellis Lake, 1219 m, 62°16.6′ N 142°56′ W, *M. Cook 3032*, 21 June 1997.

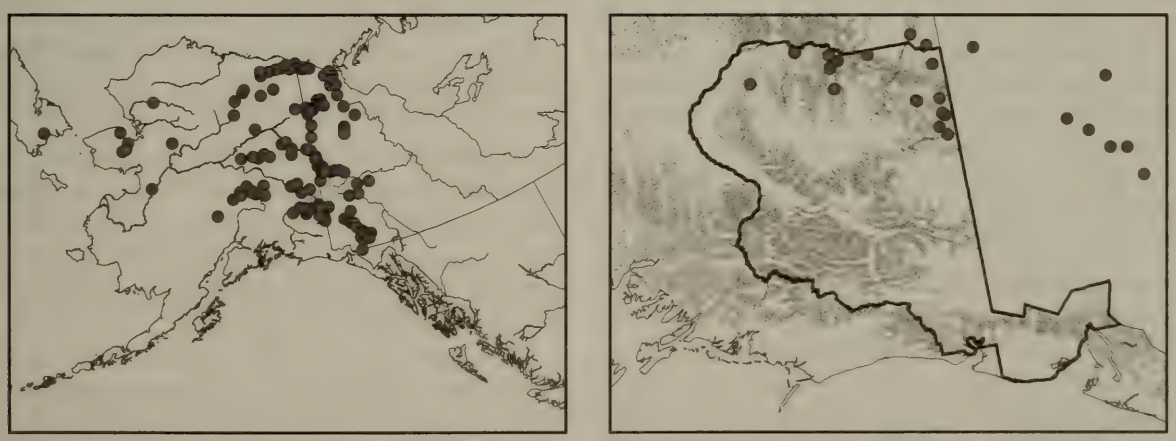
This species is circumpolar with an arctic-alpine distribution. It had been collected in the Wrangell Mountains



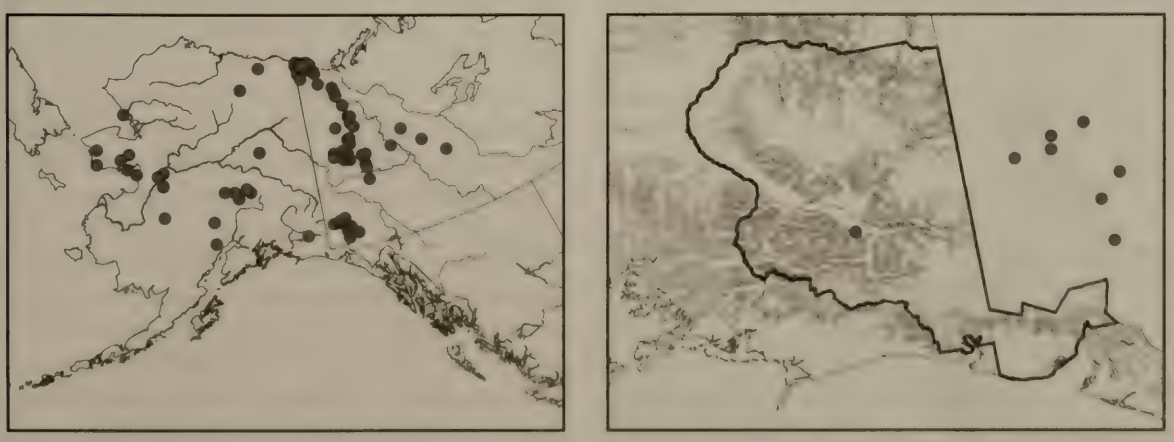
89. Silene involucrata ssp. *involucrata*



90. Silene menziesii



91. Silene repens



92. Silene uralensis ssp. *uralensis*

(Bonanza Ridge, 1219 m, 61°30′ N 142°51′ W, *Nordell and Schmitt 622*, 1967 (ALA, LD) (Nordell and Schmitt 1977; Hultén 1968)) and in the St. Elias Mountains (head of Chitina River, *H.M. Laing 228*, 1925 (CAN) (Porsild 1938; Hultén 1941-1950)). The specimens cited above extend its range 57 km to the east into the Chugach Mountains, 84 km to the northwest in the Wrangell Mountains, 122 km to the northwest into the Mentasta Mountains, 126 km north into the Nutzotin Mountains and 68 km north into the St. Elias Mountains. These collections connect its range 186 km to the northwest in the Alaska Range (Mt. Hayes Quad: 63°37.0′ N 146°43.0′ W, *L.J. Palmer 665*, 15 June 1941 (ALA)) with the range 116 km to the east in the Yukon Territory (Cody 1996). Map 89.

Silene menziesii Hook., Menzies' Campion — ST. ELIAS MOUNTAINS: rare in bare soil around rodent burrows in alpine forb herbaceous meadow, ridge between Logan and Walsh Glaciers, 1951 m, 60°53.94′ N 141°6.75′ W, *C. Roland 95-180*, 12 July 1995; *C. Roland 95-184*, 13 July 1995; *M. Cook 95217*, 13 July 1995.

This North American cordilleran species was collected on the upper Chitina River by Hamilton M. Laing in 1925 (#61, 62 (CAN)). Porsild identified this material as *S. williamsii* Britt. (Porsild 1938), but Hitchcock and Maguire (1947) re-determined it as *S. menzeisii*. This determination also fits the distribution pattern better than *S. williamsii*, which is an Alaska-Yukon endemic, species which are more common in the mountains of the Alaska Range in the Park. The station in Hultén (1968) for Laing's collection on the upper Chitina River is near Hubrick's Landing where Laing had his base camp while the expedition was climbing Mt. Logan from May 18 to July 6 (Lambart 1926a, 1926b). However, he surveyed from Hubrick's Landing up river to Logan and Walsh Glaciers, so we cannot be certain where this collection was made. The collections in the Park are 403 km southeast of the closest station in Alaska (Talkeetna Mountains, 62°55.0′ N 149°40.0′ W, *P. Wagner 74*, 4 July 1988 (ALA)) and 175 km west of collections in the Yukon Territory (Cody 1996). Map 90.

Silene repens Patrin. — MENTASTA MOUNTAINS: occasional in dry, rubbly areas on S-facing bluff, Caribou Creek, 975 m, 62°35.1′ N 143°28.1′ W, *Roland & D'Auria 97-011*, 26 June 1997; occasional on S-facing dry forb herbaceous slope, Devil's Mountains, 942 m, 62°24.95′ N 142°54.86′ W, *M. Cook 96236*, *C. Roland 96-223*, 22 June 1996; scattered in organic soil with lichens on rock outcrops on ridge, Devil's Mountains, 1530 m, 62°25.62′ N 142°53.93′ W, *M. Cook 96281*, 7 July 1996; scattered in greenstone rubble, limestone ridge between Soda and Platinum Creeks, 1494 m, 62°31.2′ N 142°54.03′ W, *C. Roland 95-142*, 5 July 1995; scattered along south side of ridge on exposed rock outcrops and gravel areas, between Totschunda and Platinum Creeks, 1494 m, 62°27.82′ N 142°46.27′ W, *M. Cook 3158*, 9 July 1998. NUTZOTIN MOUNTAINS: alpine scree slopes, Ptarmigan Lake, 1234 m, 61°53.78′ N 141°8.81′ W, *J. Barnes 96-261*, 12 August 1996; rock slope, Rocker Creek, 1615 m, 62°9.56′ N 145°0.76′ W, *M. Duffy 92186*, 9 July 1992; rare on W-facing open low birch scrub slope, Horsfeld Creek, 1128 m, 62°2′ N 141°11′ W, *Parker & Gracz 6906*, 13 August 1996; occasional in steppe and open poplar woodland, Rock Lake, 1119 m, 61°48.7′ N 141°16.57′ W, *C. Roland 96-040*, 5 June 1996; common in talus meadow, Wiki Creek, 1411 m, 61°54.46′ N 141°10.68′ W, *C. Roland 96-107*, 11 June 1996; scattered in *Dryas*-low scrub, Alder Creek, 1554 m, 62°28.44′ N 142°15.06′ W, *M. Cook 95128*, 29 June 1995; rare on SE-facing subalpine meadow, Carden Hills, 1311 m, 62°18.44′ N 141°11.55′ W, *C. Roland 94-141A*, 26 June 1994; S-facing bluff, White River between Cub and Traver Creeks, 1219 m, 61°44.3′ N 141°9.5′ W, *C. Roland 95-074*, 21 June 1995; few scattered in unstable gravel and cobble sized scree, rhyolite knob, Wiki Basin, 1524 m, 61°54.77′ N 141°11.05′ W, *M. Cook 3184*, 15 July 1998; scattered on gravel scree slope, Carl Creek, 1791 m, 62°3.14′ N 141°35.06′ W, *M. Cook 3148*, 1 July 1998; patchy on boulder slope, Carl Creek, 1590 m, 62°2.69′ N 141°33.97′ W, *M. Cook 3150*, 2 July 1998. WRANGELL MOUNTAINS: few in bare mineral soil, Nabesna River bluff, 1106 m, 62°15.05′ N 142°54.68′ W, *M. Cook 96193*, *C. Roland 96-171*, 19 June 1996.

This speices is amphiberingean with a boreal-montane distribution. It was collected on the Sanford River (*W.L. Poto 103*, 1902 (US) (Poto 1902*, Hultén 1943)) and the Nabesna River (*Schrader & Hartman 61*, 1902 (US) (Hultén 1943)). However, these stations do not appear in Hultén's 1968 flora. The specimens cited above extend its range 71 km into the Mentasta Mountains and 181 km east into the Nutzotin Mountains from the collections on the Sanford and Nabesna Rivers and 202 km south from stations in the Tanana Valley (Hultén 1968). Map 91.

Silene uralensis (Rupr.) Bocquet ssp. *uralensis* (*Melandrium macrospermum* Pors., *S. macrosperma* (Porsild) Hultén), Largefruit Catchfly — CHUGACH MOUNTAINS: SE-facing ridgetop lichen tundra, vic. Chakina River, 1768 m, 61°6.19′ N 142°55.03′ W, *C. Roland 94-184C*, 8 July 1994.

This species is circumpolar with an arctic-alpine distribution. The specimen cited above extends its range 410 km to the southeast into the Chugach Mountains from a station in the Healy Quad (Sable Pass, 63°34.0′ N 149°40.0′ W, *A. Murie s.n.*, 19 July 1964 (ALA)) and connects the range 148 km to the east in the Yukon Territory (Cody 1996). Map 92.

Silene williamsii Britt. (Britt.) Hult. (*S.* Hook. ssp. *williamsii* (Britt.) Hult.), Williams Campion — MENTASTA MOUNTAINS: occasional in seral herb vegetation on Nabesna River floodplain at Totschunda Creek, 725 m, 62°26.94′ N 42°40.8′ W, *M. Cook 96249*, *C. Roland 96-253*, 23 June 1996. WRANGELL MOUNTAINS: stabilized river terrace with high lichen cover, 2 mi SE of Whitham Lake, 817 m, 62°18.96′ N 142°54.07′ W, *C. Roland 96-197*, 20 June 1996; occasional in sandy areas of river terrace with patchy open low shrubs and mixed forbs, Nabesna River at Jacksina River, 759 m, 62°21.51′ N 142°52.87′ W,

M. Cook 96221, 6 June 1996; scattered in cobbles and sand on river terrace, Copper River, across from Black Mountain, 945 m, 62°19.02′ N 143°47.44′ W, *C. Roland 96-904*, 10 August 1996.

This Alaska-Yukon endemic was collected by F. W. Went in the vicinity of Copper Center just outside the Park in 1934 (Hultén 1943). The specimens cited above extend its range 151 km northeast into the Mentasta Mountains and connect the range 99 km to the north in the Tanacross Quad (Slippery Rock Creek, 63°21.0′ N 143°29.0′ W, *L.A. Spetzman 721*, 19 July 1957 (ALA)) with the station at Copper Center. This species is rare in the Yukon Territory (Douglas et al. 1981). Map 93.

Stellaria alaskana Hult., Alaska Starwort — MENTASTA MOUNTAINS: limestone slope, upper Trail Creek, 1341 m, 62°37.09′ N 143°16.06′ W, *M. Potkin 95-042*, 26 July 1995; scattered at base of NE-facing limestone scree slope, headwaters of Lost Creek, 1722 m, 62°36.45′ N 143°12.03′ W, *M. Cook 95176*, 7 July 1995; limestone slope, upper Trail Creek, 1341 m, 62°37.09′ N 143°16.06′ W, *A. Leggett 95-052*, 7 July 1995; rare on rock outcrops, Devils's Mountain, 1530 m, 62°25.62′ N 142°53.93′ W, *C. Roland 96-351*, 3 July 1996. NUTZOTIN MOUNTAINS: scattered in steep, unstable granitic rubble, Carl Creek, 1920 m, 62°3.52′ N 141°36.27′ W, *C. Roland 95-022*, 13 June 1994; moist scree on N-facing slope, Baultoff Creek, 1707 m, 62°9.13′ N 141°14.51′ W, *M. Cook 94177A*, 27 June 1994; scattered underneath rocks in moist loamy sand, Klein Creek, 1747 m, 62°2.29′ N 141°19.88′ W, *M. Cook 95012*, 15 June 1995; scattered at base of scree slope, alpine basin at headwaters of Stone Creek, 1585 m, 62°25.78′ N 142°22.11′ W, *M. Cook 95104*, 27 June 1995; scattered at base of rock outcrops, headwaters of Alder Creek, 1554 m, 62°28.44′ N 142°15.06′ W, *M. Cook 95138*, 30 June 1995. ST. ELIAS MOUNTAINS: scattered on NE-facing unstable volcanic scree slope, Mt. Natazhat, 1716 m, 61°35.38′ N 141°1.83′ W, *M. Cook 95075*, *C. Roland 95-071*, 20 June 1995. WRANGELL MOUNTAINS: N-facing scree slope, Lime Creek ridge, 1707 m, 61°47.2′ N 141°49.06′ W, *M. Cook 92498*, 7 July 1992; S-facing granite boulder slope, Cooper Pass, 1942 m, 62°17.16′ N 142°31.44′ W, *C. Roland 94-285B*, 24 July 1994; scattered on upper slope of cinder cone, Cone Ridge, 2073 m, 62°8.21′ N 143°18.47′ W, *M. Cook 94378*, *C. Roland 94-315*, 25 July 1994; rare in tundra, Crystalline Hills, 1585 m, 61°23.59′ N 143°31.85′ W, *C. Roland 95-251*, 18 July 1995; scattered on E-facing boulder slope, Fish Creek, 1067 m, 62°16.92′ N 142°58.99′ W, *M. Cook 95318*, 27 July 1995; Lakes Plateau, 1890 m, 62°4.4′ N 143°23.5′ W, *Leggett & Potkin 95-073, 95-084*, 28 July 1995; scattered on scree slope, Black Mountain, 1481 m, 62°20.85′ N 143°44.9′ W, *M. Cook 95145*, 7 July 1995; steep N-facing scree, Nikolai Pass, 1280 m, 61°26′ N 142°40′ W, *Batten & Barker 96-028*, 23 July 1996; scree near rocky ridge, VABM Sentinel, west of Nizina Glacier, 1829 m, 61°39′ N 142°32′ W, *Batten & Barker 96-124*, 25 July 1996 (ALA); scattered in rhyolite scree on SE-facing slope Kuskulana Pass, 1545 m, 61°33.72′ N 143°39.7′ W, *C. Roland 96-708*, 26 July 1996; occasional in sandy soil on S-facing slope, 6 km east of Snyder Peak, 1524 m, 62°4.47′ N 144°30.51′ W, *C. Roland 96-376*, 5 July 1996; occasional in *Rhacomitrium* at head of scree slope, Kuskulana Pass, 1545 m, 61°33.72′ N 143°39.7′ W, *M. Cook 96549*, 7 July 1996; rare along gravel creekbed, upper Skookum trail, 1563 m, 62°25.83′N 143°6.91′W, 1572 m, *M. Cook 3533*, 7 July 1999; scattered on scree slope, Grizzly Lake, 1312 m, 62°14.05′N 143°20.98′W, *J. Allen s.n.*, 27 July 2000.

This Alaska-Yukon endemic was known previously from three localities in the Wrangell-St. Elias Mountains: Russell Glacier (61°42.0′ N 141°45.0′ W, *D. F. Murray 2170*, 11 August 1968 (ALA)), Sheep Glacier (61°42.0′ N 141°39.0′ W, *D.F. Murray 2251*, 15 August 1968 (ALA)) and Chitistone Pass (61°37′ N 142°3′ W, *R. Scott 1761* (MICH), Scott (1968) and from a station near Mentasta Pass (Hultén 1968). The specimens cited above extend the range 139 km west in the Wrangell Mountains, 85 km north into the Nutzotin Mountains and connect the distribution to the northwest in the Alaska Range with collections 40 km to the east in the Yukon Territory Cody (1996). It is rare in Alaska (GS S3) and in the Yukon Territory (Douglas et al. 1981). Map 94.

Stellaria umbellata Turcz., Umbrella Starwort — CHUGACH MOUNTAINS: occasional in mesic tundra in limestone unit between Iron & Lime Creeks, 1798 m, 61°1′ N 141°53.18′ W, *M. Cook 94430A*, 8 August 1994; scattered in mud seeps, Verde Ridge, 1554 m, 61°14.03′ N 143°28.52′ W, *Roland & D'Auria 96-478*, 11 July 1996; occasional in moist calcareous gravel, Granite Creek, 1829 m, 61°0.22′ N 141°51.1′ W, *C. Roland 96-737*, 28 July 1996; moist N-facing scree, West Fork Goat Creek, 1487 m, 60°59.5′ N 142°1′ W, *Batten & Barker 96-312A*, 29 July 1996 (ALA). NUTZOTIN MOUNTAINS: patchy in sheep bed at base of talus slope, Stone Creek, 1585 m, 62°25.78′ N 142°22.11′ W, *M. Cook 95101*, 27 June 1995. ST. ELIAS MOUNTAINS: rare in wet gravel, Mt. Chitina, 2073 m, 60°57.74′ N 141°17.33′ W, *C. Roland 95-194*, 14 July 1995; *M.Cook 95248*, 16 July 1995. WRANGELL MOUNTAINS: common in saturated soil of seep, Hasen Creek, 1835 m, 61°34.06′ N 142°18.33′ W, *C. Roland 96-638*, 23 July 1996.

This amphiberingean arctic-alpine species is rare in Alaska (G4 S2S3) and the Yukon Territory (Douglas et al. 1981). It was known from Chitistone Pass in the Wrangell Mountains (61°37′ N 141°58′ W, *D. F. Murray 1044*, (CAN) (Murray 1968)). The specimens cited above extend its range 90 km south into the Chugach Mountains, 93 km north into the Nutzotin Mountains and connect its distribution 125 km to the west in the Valdez Quad (Valdez Glacier, 61°08.0′ N 146°10.0′ W, *L. A. & E.G. Viereck 2229*, 10 August 1957 (ALA)) with a station 151 km to the east in the Yukon Territory (Cody 1996). Map 95.

CERATOPHYLLACEAE

Ceratophyllum demersum L., Coon's Tail — COPPER RIVER BASIN: dominant, submerged in shallow water next to shore, pond at 2 km, Old Edgerton Highway, 415 m, 61°49.3′ N 145°10.7′ W, *M. Cook 95371*, 8 August 1995.

The specimen cited above extends the range of this species 201 km south from the Healy Quad (vic. Cantwell, 63°24.0′ N 148°56.0′ W, *G. Smith 2243*, 6 September 1953 (ALA)). It is rare in the Yukon Territory (Douglas et al. 1981). Map 96.

NYMPHAEACEAE

Nymphaea tetragona Georgi ssp. *leibergii* (Morong) Pors., Dwarf Water Lily — CHITINA RIVER BASIN: beaver pond east of Chititu Creek, 457 m, 61°22.16′ N 142°40.29′ W, *M. Duffy 91048*, 8 July 1991; flowering along margins of pond 11 mi E of Chitina on the McCarthy Road, 427 m, 61°31.38′ N 144°10.14′ W, *M. Cook 95376*, 8 August 1995.

The specimens cited above extend the range of this species 174 km south from the Tanana River Basin (Scottie Creek, 62°41.0′ N 141°05.0′ W, *L. Vining 35*, 22 July 1979 (ALA)) and 282 km east from the Matanuska River Basin (*E. LePage 20715*, 1947 (S) (Hultén 1949)). Map 97.

RANUNCULACEAE

Caltha leptosepala DC., Mountain Marsh-Marigold — CHUGACH MOUNTAINS: mesic forb tundra, upper Tebay Lake, 1219 m, 61°12.18′ N 144°23.8′ W, *M. Duffy 91112*, 12 August 1991; forming continuous mats in wet moss stringers, West Fork Goat Creek, 1487 m, 60°59.8′ N 142°11.8′ W, *M. Cook 96657*, 31 July 1996; patchy in moist hummocky tundra in moist soil, Grant Creek plateau, 1250 m, 61°17.65′ N 143°56.34′ W, *Cook & Losso 96347*, 7 July 1996; numerous in wet moss along creek, alpine valley 5.25 mi SE of Spirit Mountain, 1006 m, 61°16.84′ N 144°29.86′ W, *M. Cook 96444*, 7 July 1996; occasional in mesic forb herbaceous meadow, vic. 12-mile Creek, 1326 m, 60°50.21′ N 142°30.85′ W, *M. Cook 96592*, 7 July 1996; rare in moist areas around alpine lake, Nerelna Creek plateau, 1372 m, 61°26.66′ N 144°17.69′ W, *Roland & D'Auria 96-418*, 8 July 1996; scattered in subarctic lowland sedge wet meadow, upper Tebay Lake, 579 m, 61°11′ N 144°24′ W, *Parker & Gracz 6751*, 7 August 1996. ST. ELIAS MOUNTAINS: alpine herbaceous meadow, Karr Hills, 549 m, 60°8.66′ N 141°16.44′ W, *K.A. Beck s.n.*, 12 August 1987.

This species is North American with a cordilleran distribution. The collections cited above extend its range 192 km east into the Chugach Mountains and 267 km southeast into the southern St. Elias Mountains from a station at Thompson Pass (*J.P. Anderson 1901*, 30 July 1935 (S) (Hultén 1943)) and connect the range 195 km to the east in the Yukon Territory (Cody 1996). Map 98.

Coptis trifolia (L.) Salisb., Trifoliate Goldthread — CHUGACH MOUNTAINS: ericaceous shrub bog, Middle Fork of the Bremner River, 869 m, 60°55.05′ N 143°43.86′ W, *Duffy & Barnes 96-096*, 8 August 1996. GULF OF ALASKA: ericaceous shrub/graminoid herbaceous bog, between Porcupine Creek and Yakataga River, Robinson Mountains, 488 m, 60°4.8′ N 142°12.8′ W, *M. Duffy 9217*, 11 June 1992.

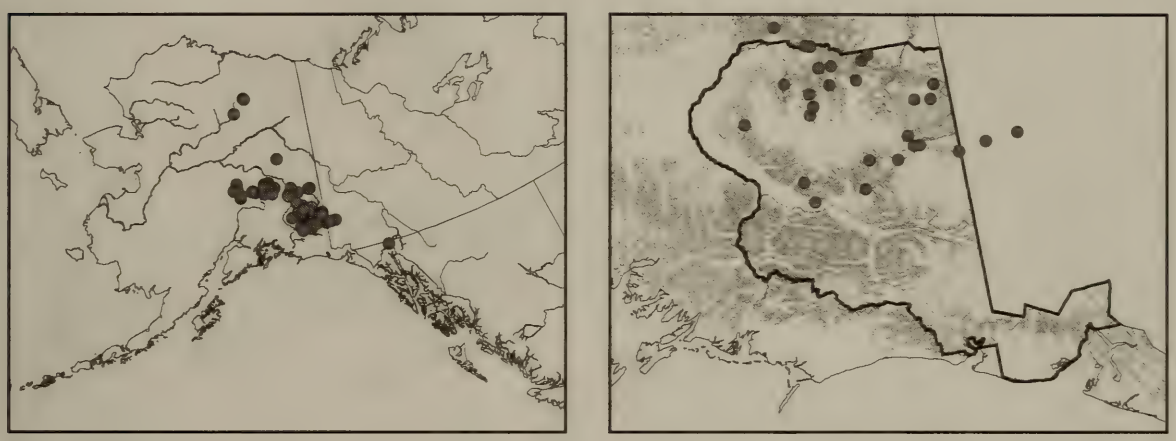
This species is amphiberingean with a boreal-montane distribution. The specimens cited above extend its range 91 km northeast in the Chugach Mountains from a collection at Katella (60°12.0′ N 144°31.0′ W, *J. Ver Hoef 29*, 21 June 1979 (ALA)), 136 km east to the Robinson Mountains from a collection at Cape St. Elias (59°56.0′ N 144°23.0′ W, *Cunningham & Stanford 130-78*, 4 June 1978 (ALA)) and connect with a station 155 km to the east at Yakutat (*F. Funston s.n.*, 1 July 1892 (US) (Coville and Funston 1896, Hultén 1941-1950)). Map 99.

Delphinium brachycentrum Ledeb., Northern Larkspur — NUTZOTIN MOUNTAINS: scattered on extensive SW-facing gravel slopes, Baultoff Creek, 1707 m, 62°9.13′ N 141°14.51′ W, *C. Roland 94-160*, 28 June 1994; occasional on unstable scree slope, headwaters of Alder Creek, 1554 m, 62°28.44′ N 142°15.06′ W, *M. Cook 95134*, 30 June 1995.

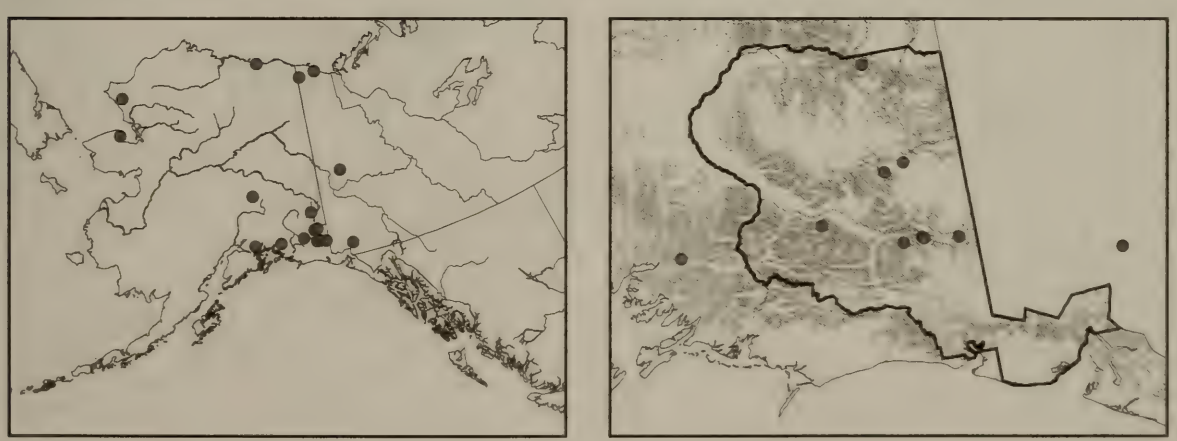
This amphiberingian arctic-alpine species is rare in the Yukon Territory (Douglas et al. 1981). The specimens cited above extend its range 203 km south into the Nutzotin Mountains from the Mt. Hayes Quad (Horn Mt, 63°38.0′ N 144°44.0′ W, *L.A. Spetzman 154*, 25 July 1957 (ALA)). Map 100.

Ranunculus gelidus Karel. & Kiril. ssp. *grayi* (Britt.) Hult. — CHUGACH MOUNTAINS: occasional on W-facing scree slope, Iron Creek, 1798 m, 61°1′ N 141°53.18′ W, *M. Cook 94437*, 6 August 1994; loose marble gravel on SW-facing slope, Granite Creek, 1829 m, 61°0.22′ N 141°51.1′ W, *C. Roland 96-745*, 28 July 1996. MENTASTA MOUNTAINS: occasional in unstable scree, Devil's Mountain, 1530 m, 62°25.62′ N 142°53.93′ W, *M. Cook 96280A*, 7 July 1996; common in calcareous gravel, Totschunda Creek, 1280 m, 62°27.63′ N 142°12.44′ W, *C. Roland 96-292*, 24 June 1996; scattered on moist scree, headwaters of Lost Creek, 1722 m, 62°36.45′ N 143°12.03′ W, *M. Cook 95166*, 4 July 1995; upper Trail Creek, 1341 m, 62°37.09′ N 143°16.06′ W, *M. Potkin 95-055*, 28 July 1995; occasional in steep gully, Lost Creek, 1189 m, 62°35′ N 143°9.1′ W, *Roland & D'Auria 97-061*, 26 June 1997. NUTZOTIN MOUNTAINS: few on basalt tuff slope, Wiki Creek, 1411 m, 61°54.46′ N 141°10.68′ W, *M. Cook 96088*, 10 June 1996; S-facing talus slope, Rocker Creek, 1433 m, 61°54.8′ N 141°2.03′ W, *M. Cook 94136*, 23 June 1994; Carl Creek, 1920 m, 62°3.52′ N 141°36.27′ W, *M. Cook 95028*, 16 June 1994; scattered on unstable scree, Alder Creek, 1554 m, 62°28.44′ N 142°15.06′ W, *M. Cook 95133*, 30 June 1995; rare in platy rubble on bluff, Rock Lake, 1119 m, 61°48.7′ N 141°16.57′ W, *C. Roland 96-036*, 5 June 1996; rare on steep talus slope, Wiki Creek, 1411 m, 61°54.46′ N 141°10.68′ W, *C. Roland 96-075*, 8 June 1996; SW-facing ravine, Baultoff Creek,

93. Silene williamsii

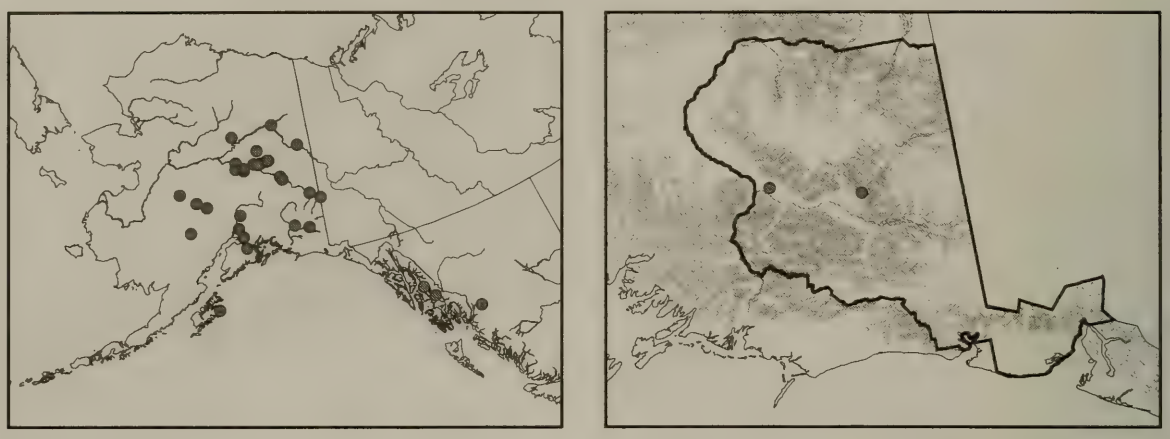


94. Stellaria alaskana



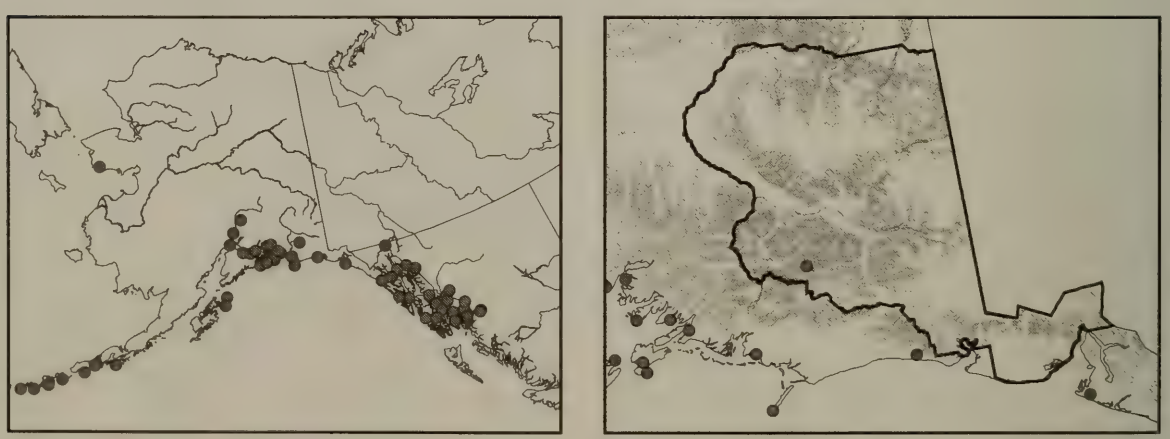
95. Stellaria umbellata

96. Ceratophyllum demersum

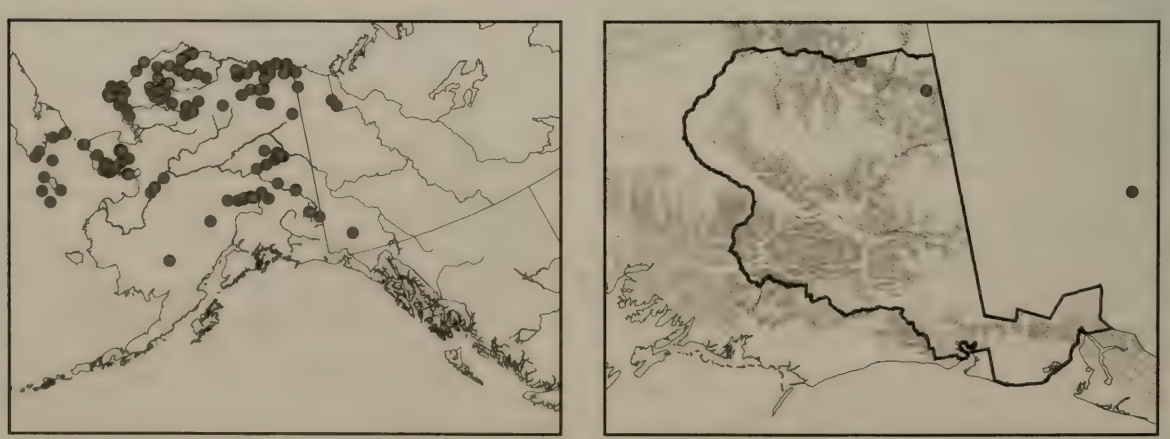


97. *Nymphaea tetragona* ssp. *leibergii*

98. *Caltha leptosepala*

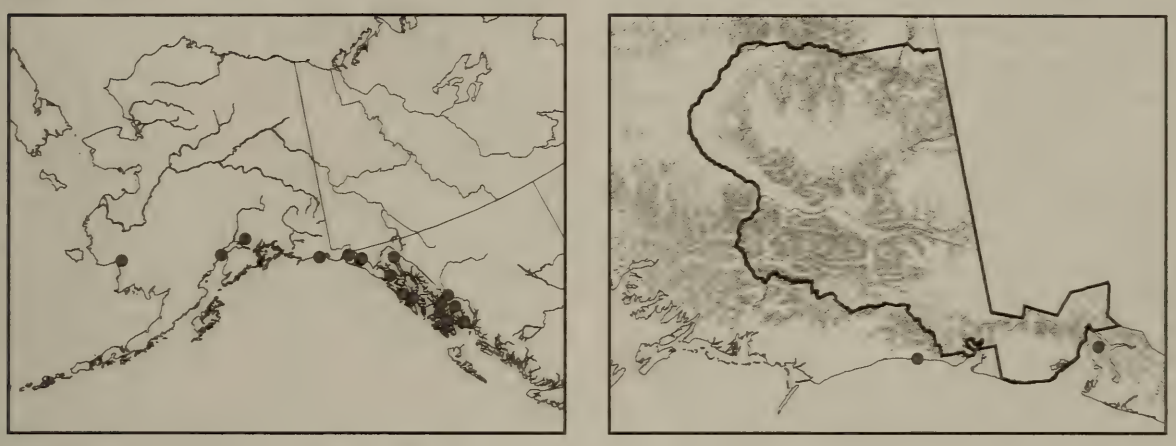


99. *Coptis trifolia*

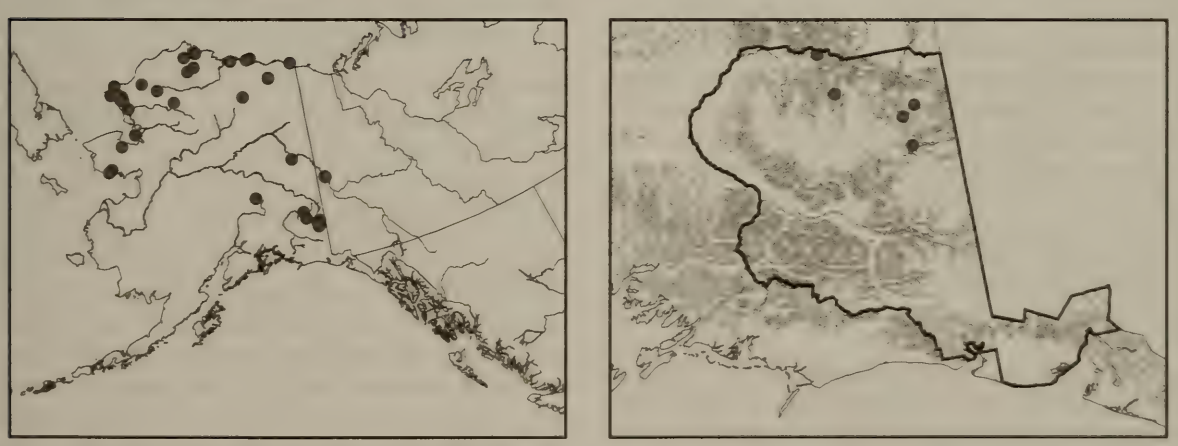


100. *Delphinium brachycentrum*

101. Ranunculus gelidus ssp. *grayi*



102. Ranunculus pacificus



103. Ranunculus pedatifidus ssp. *affinis*

104. Ranunculus sulphureus var. *sulphureus*

1707 m, 62°9.13′ N 141°14.51′ W, *Cook & Roland 94-144B, 94189A*, 27 June 1994; occasional in unstable granite scree, Carl Creek, 1920 m, 62°3.52′ N 141°36.27′ W, *M. Cook 95009*, 14 June 1994; Klein Creek, 1747 m, 62°2.29′ N 141°19.88′ W, *M. Cook 95011*, 15 June 1995; volcanic plateau between Bryan and Willow Creeks, 1829 m, 61°58.97′ N 141°50.03′ W, *M. Cook 95050*, 18 June 1995. WRANGELL MOUNTAINS: Jaegar Mesa, 1893 m, 62°15.9′ N 143°1.24′ W, *Moran & Roland 95-43*, 1 July 1995; Lime Creek, 1646 m, 61°46.25′ N 141°50.36′ W, *M. Cook 94114*, 21 June 1994; Nabesna Glacier moraine, 1768 m, 61°56.6′ N 143°0.00 W, *M. Cook 9266, M. Duffy 92114*, 26 June 1992; Lime Creek, 1707 m, 61°28.41′ N 141°29.44′ W, *M. Cook 92497, M. Duffy 92143*, 7 July 1992; Alice Peak, 1628 m, 61°39.82′ N 144°7.76′ W, *C. Roland 96-392*, 5 July 1996; Iron Mountain, 1868 m, 61°37.85′ N 144°1.01′ W, *C. Roland 96-584*, 16 July 1996; Chitistone Falls, 1177 m, 61°32.27′ N 142°11.49′ W, *C. Roland 96-628*, 22 July 1996; Fish Creek, 1067 m, 62°16.92′ N 142°58.99′ W, *M. Cook 95319*, 27 July 1995; Lakes Plateau, 1890 m, 62°4.4′ N 143°23.5′ W, *M. Potkin 95-123*, 30 July 1995; Crystalline Hills, 1585 m, 61°23.59′ N 143°31.85′ W, *M. Cook 95275*, 18 July 1995; north slope of Mt. Sanford, 1722 m, 62°23.4′ N 144°15.9′ W, *C. Roland 94-006*, 6 June 1994; Cone Ridge, 2073 m, 62°8.21′ N 143°18.47′ W, *C. Roland 94-305B*, 27 July 1994 (WRST); Jaegar Mesa, 1893 m, 62°15.9′ N 143°1.24′ W, *C. Roland 95-111*, 1 July 1995.

This species is amphiberingean with a cordilleran distribution. It was collected in the St. Elias Mountaints at Russell Glacier (61°42.0′ N 141°45.0′ W, *D.F. Murray 2190*, 11 August 1968 (ALA)) and Guerin Glacier (61°37.0′ N 141°50.0′ W, *D.F. Murray 2041*, 3 August 1968 (ALA)). The new localites cited above extend its range 188 km west into the Wrangell Mountains, 113 km north into the Nutzotin Mountains and 81 km south into the Chugach Mountains. Map 101.

Ranunculus pacificus (Hult.) Benson, Pacific Buttercup — GULF OF ALASKA: herbaceous/alder scrub, Cape Yakataga, 50 m, 60°3.32′ N 142°18.3′ W, *M. Duffy 9205*, 10 June 1992.

The specimen cited above from Cape Yakataga connects the distribution of this Pacific Coastal species 418 km to the west in the Tyonek Quad (Lower Fish Creek, 61°22.0′ N 150°31.0′ W, *J.A. Erickson 13*, 18 June 1963 (ALA)) with collections 160 km to the southeast near Yakutat (Ankow River, *E.P. Walker s.n.*, 1904 (US) and *L.V. Piper 4468*, 1904 (US) (Hultén 1943)). It is rare in Alaska (G3 S3). Map 102.

Ranunculus pedatifidus Sm. ssp. *affinis* (R. Br.) Hult., Northern Buttercup — MENTASTA MOUNTAINS: mesic fissure of outcrop, Lost Creek, 1646 m, 62°34.58′ N 143°5.58′ W, *C. Roland 94-261*, 23 July 1994. NUTZOTIN MOUNTAINS: *Dryas* tundra, Beaver Butte, 1829 m, 61°58.97′ N 141°50.03′ W, *M. Cook 95054*, 18 June 1995; locally abundant in turfy area, Carl Creek, 1920 m, 62°3.52′ N 141°36.27′ W, *C. Roland 95-023*, 13 June 1994. ST. ELIAS MOUNTAINS: mesic meadow in scrub, White River, 1158 m, 61°44.87′ N 141°45.4′ W, *M. Duffy 92139*, 6 July 1992. WRANGELL MOUNTAINS: few in rocky area, Nabesna River bluff, 1106 m, 62°15.05′ N 142°54.68′ W, *M. Cook 96185, C. Roland 96-163*, 19 June 1996.

This species is circumpolar with an arctic-alpine distribution. These localites extend its range south 126 km into the Wrangell Mountains and 144 km into the Nutzotin Mountains from a station near Northway (Hultén 1968). Map 103.

Ranunculus sulphureus Soland, var. *sulphureus* Sulphur Buttercup — NUTZOTIN MOUNTAINS: moist sedge meadow, Solo Flats, 1402 m, 62°11′ N 143°31.42′ W, *M. Duffy 92155*, 7 July 1992; occasional in seeps, Wiki Creek, 1411 m, 61°54.46′ N 141°10.68′ W, *C. Roland 96-065*, 8 June 1996; abundant in wet seeps, Beaver Butte, 1829 m, 61°58.97′ N 141°50.03′ W, *C. Roland 95-058*, 18 June 1995. WRANGELL MOUNTAINS: Jaegar Mesa, 1893 m, 62°15.9′ N 143°1.24′ W, *Moran & Roland 95-29*, 30 June 1995; mesic sedge meadow on tundra, Lakes Plateau, 1890 m, 62°4.4′ N 143°23.5′ W, *Potkin & Leggett 95-086*, 29 July 1995; sedge tundra, Cheshnina Plateau, 1640 m, 61°50.33′ N 144°22.5′ W, *M. Duffy 91089*, 21 July 1991.

This circumpolar arctic-alpine plant was collected at Skolai Pass in the Wrangell Mountains (Scott 1968). The specimens cited above extend its range 149 km east into the Wrangell Mountains. Map 104.

Ranunculus trichophyllus Chaix in Villars var. *eradicatus* (Laestadius) W.B. Drew, Thread-Leaf Water-Crowfoot — CHUGACH MOUNTAINS: Grant Creek, 853 m, 61°18.16′ N 143°51.87′ W, *Cook & Losso 96337*, 7 July 1996. WRANGELL MOUNTAINS: occasional in shallow water of pond, 911 m, 62°24.53′ N 143°42.68′ W, *C. Roland 96-918*, 11 August 1996; floating aquatic, Fish Creek, 1067 m, 62°16.92′ N 142°58.99′ W, *M. Cook 95324A*, 29 July 1995.

This species is cirumpolar with a widespread distribution. The specimens cited above extend its range south 181 km into the Wrangell Mountains and 301 km into the Chugach Mountains from a station near Healy Lake (Hultén 1968). Map 105.

PAPAVERACEAE

Papaver alboroseum Hult., Pale Poppy — CHUGACH MOUNTAINS: talus slope, Flood Creek, 1829 m, 61°42.88′ N 141°58.65′ W, *M. Duffy 91059*, 16 July 1991; rare on S-facing boulder slope, Juniper Island, 1291 m, 60°36.24′ N 142°21.69′ W, *M. Cook 94259*, 11 July 1994; rare on W-facing limestone scree, ridge between Iron & Lime Creeks, 1798 m, 61°1′ N 141°53.18′ W, *M. Cook 94439*, 8 August 1994; occasional in old slide debris, pass between Amy Creek and Klu River, 1164 m, 61°4.01′ N 143°34.83′ W, *C. Roland 96-530*, 13 July 1996; few in loose rubble and sand, E Fork Kiagna River,

1487 m, 60°59.8′ N 142°11.8′ W, *C. Roland 96-844*, 31 July 1996. NUTZOTIN MOUNTAINS: rare on S-facing talus slope, Carl Creek, 1920 m, 62°3.52′ N 141°36.27′ W, *M. Cook 94112A*, 20 June 1994; rare on barren S facing granidorite slope, Carl Creek, 1859 m, 62°3.07′ N 141°35.01′ W, *M. Cook 94128*, 22 June 1994. ST. ELIAS MOUNTAINS: scattered on scree slopes, Mt. Chitina, 2073 m, 60°57.74′ N 141°17.33′ W, *M. Cook 95237*, *C. Roland 95-198B, 95-208,* 15 July 1995. WRANGELL MOUNTAINS: rare in granitic scree, Crystalline Hills, 1585 m, 61°23.59′ N 143°31.85′ W, *C. Roland 95-241*, 18 July 1995; few in gravel scree, Iron Mountain, 1868 m, 61°37.85′ N 144°1.01′ W, *M. Cook 96464*, 16 July 1996; rubble and talus slope, Bonanza Ridge, 1768 m, 61°30.7′ N 142°49.85′ W, *G. Dodge s.n.*, 10 August 1993; patchy on barren slope, Grotto Creek, 1847 m, 61°30.56′ N 142°24.79′ W, *M. Cook 96502*, 23 July 1996; few in gravel scree, alpine lake basin E side of Lakina Glacier, 1219 m, 61°33.64′ N 143°19.01′ W, *M. Cook 96548*, 24 July 1996; gently sloping gravel barrens, Nikolai Mine, 1695 m, 61°27′ N 142°39′ W, *Batten & Barker 96-081*, 24 July 1996; rare in moist gravel, volcanic ridge 1 km east of Snyder Peak, 1524 m, 62°4.47′ N 144°30.51′ W, *C. Roland 96-384*, 5 July 1996; few in moist gravel, Cheshnina Plateau, 1399 m, 61°48.04′ N 144°6.27′ W, *M. Cook 96711*, 5 August 1996.

This poppy, rare in Alaska (G3G4 S3), was previously known from two localities in the Wrangell-St. Elias Mountains: Sheep Glacier (61°42.48′N 141°38.59′W, *D. F. Murray 2212*, 14 August 1968 (ALA) (Murray 1971)) and Bonanza Ridge (61°30′ N 142°51′ W, *Nordell & Schmitt 1, 101, 160, 166, 171, 301, 464* (LD & ALA) (Nordell & Schmitt)). It is now known from 17 additional localities in the Park including the Nutzotin and Chugach Mountains up to 108 km distant from the earlier collections. These collections are 161 km disjunct from the range of this species to the west in the Anchorage Quad (Eklutna Glacier, 61°17.0′ N 148°58.0′ W, *S.L. Welsh 4178*, 18 June 1965 (ALA)) and 135 km south of the range to the north in the Mt. Hayes Quad (Rainbow Ridge, 63°15.0′ N 145°40.0′ W, *C. Parker 1710*, 2 August 1985 (ALA)). Map 106.

Papaver radicatum Rottball ssp. *kluanense* (D. Löve) D.F. Murray (*P. kluanensis* D. Löve, *P. freedmanianum* D. Löve), Arctic Poppy — MENTASTA MOUNTAINS: rare in runnels of soil in fine limestone scree with alpine herbs, ridge between Little Jack and Trail Creeks, 1615 m, 62°36.05′ N 143°17.63′ W, *C. Roland 95-010*, 6 June 1995. NUTZOTIN MOUNTAINS: few on rhyolite talus slope with sparse *Dryas*-lichen-alpine herbs, vic. Wiki Peak, 1433 m, 61°53.9′ N 141°9.51′ W, *M. Cook 94126*, 16 June 1994; few in unstable, granodiorite scree, S-facing slope with sparse alpine herbs, Carl Creek, 1859 m, 62°3.07′ N 141°35.01′ W, *M. Cook 94127A*, 22 June 1994; few localized on barren, unstable, granodiorite cobble and boulder scree S-facing slope, 1585 m, 62°2.87′ N 141°34.46′ W, *M. Cook 95002, C. Roland 95-029*, 13 June 1995; occasional in crevices and in gravel scree of boulder field, sparsely vegetated with sagebrush-herbs, Rock Lake, 1119 m, 61°48.7′ N 141°16.57′ W, *M. Cook 96029*, 4 June 1996; few scattered on unstable steep S-facing rhyolite scree knob, Wiki Basin, 1524 m, 61°54.77′ N 141°11.05′ W, *M. Cook 3186*, 15 July 1998. ST. ELIAS MOUNTAINS: few in exposed ash, sparsely vegetated with seral herbs, Cub Creek, 1280 m, 61°37.27′ N 141°9.75′ W, *M. Cook 94185*, 16 June 1994; scattered at base of limestone knob in ash with seral herbs and *Dryas*, Mt. Natazhat, 1716 m, 61°35.38′ N 141°1.83′ W, *M. Cook 95070, 95078, C. Roland 95-064, 95-072,* 16 June 1995; occasional on barren N-facing gravel slope, Mt. Chitina, 2073 m, 60°57.74′ N 141°17.33′ W, *C. Roland 95-221*, 16 July 1995. WRANGELL MOUNTAINS: scattered in frost-boils on high elevation ridge of limestone, Cooper Pass, 1942 m, 62°17.16′ N 142°31.44′ W, *C. Roland 94-278*, 24 July 1994; scattered in bare mineral soil on S-facing slope, volcanic ridge between Jacksina River & Mesa Creek, 2073 m, 62°8.21′ N 143°18.47′ W, *M. Cook 94374*, 25 July 1994; large population in volcanic tuff, ridge between upper Jacksina River & Mesa Creek, 2073 m, 62°8.21′ N 143°18.47′ W, *M. Cook 94407, C. Roland 94-312, 94-313*, 26 July 1994.

This North American cordilleran poppy was known from the St. Elias Mountains of Alaska and the Yukon, vicinity of Mayo Lake in the Yukon and Eklutna Valley near Anchorage. The new localities cited above extend the range of this subspecies into the Mentasta, Nutzotin and Wrangell Mountains as far as 126 km from the earlier collections. Except for the locality disjunct 338 km to the west in the Anchorage Quad (Eklutna Valley, 61°26.0′ N 149°08.0′ W, *L. C. Marvin 2114*, 19 Jul 1985 (ALA)), these collections represent the western extension of the range of this subspecies. Map 107.

Papaver walpolei A.E. Porsild, Walpole's Poppy — MENTASTA MOUNTAINS: scattered on rubble slope, headwaters of Lost Creek, 1722 m, 62°36.45′ N 143°12.03′ W, *M. Cook 95172*, 4 July 1995.

This poppy is amphiberingean with an arctic-alpine distribution. It is rare in Alaska (G3 S3) and in the Yukon Territory (Douglas et al. 1981). The locality cited above represents the southern limit of its distribution in Alaska and the Yukon, is 970 km disjunct from populations on the Seward Peninsula in northwestern Alaska (Solomon Quad: 64°34.0′ N 163°43.0′ W, *S.D. Kildaw s.n.*, July 1987 (ALA)) and 325 km southwest of collections near Dawson in the Yukon Territory (Cody 1996). Map 108.

BRASSICACEAE

Aphragmus eschscholtzianus Andrz., Aleutian Cress — CHUGACH MOUNTAINS: moist sandy runnels on NE-facing stony slope, Verde Ridge, 1554 m, 61°14.03′ N 143°28.52′ W, *Roland & D'Auria 96-471, 96-481*, 10 July 1996; occasional in moist calcareous gravel, Granite Creek, 1829 m, 61°0.22′ N 141°51.1′ W, *C. Roland 96-739*, 28 July 1996; moist bouldery solifluction slope, West Fork Goat Creek, 1487 m, 60°59.5′ N 142°1′ W, *Batten & Barker 96-*

305, 29 July 1996; scattered in granite gravel on ridge, East Fork Kiagna River, 1487 m, 60°59.8′ N 142°11.8′ W, *M. Cook 96652*, 31 July 1996; few in wet mineral soil, Nelson Mountain, 1558 m, 61°19.37′ N 143°48.83′ W, *M. Cook 96371*, 7 July 1996; few amongst unstable shale-gravel, Grant Creek plateau, 1250 m, 61°17.65′ N 143°56.34′ W, *M. Cook 96410*, 7 July 1996; occasional in gravel stringers Bridge Creek plateau, 1871 m, 61°20.41′ N 144°6.97′ W, *M. Cook 96492*, 7 July 1996; common in mesic tundra, Nerelna Creek plateau, 1372 m, 61°26.66′ N 144°17.69′ W, *Roland & D'Auria 96-402*, 8 July 1996. MENTASTA MOUNTAINS: occasional in mesic alpine tundra, headwaters of Lost Creek, 1722 m, 62°36.45′ N 143°12.03′ W, *M. Cook 95161*, 7 July 1995. NUTZOTIN MOUNTAINS: scattered in wet moss and bare organic soil, Cooper Pass, 1942 m, 62°17.16′ N 142°31.44′ W, *M. Cook 94345*, 24 July 1994; moist bare mineral soil on NE-facing boulder slope, Klein Creek, 1747 m, 62°2.29′ N 141°19.88′ W, *M. Cook 95015*, 15 June 1995; occasional in wet mossy seep, volcanic plateau between Bryan and Willow Creeks, 1829 m, 61°58.97′ N 141°50.03′ W, *C. Roland 95-050*, 18 June 1995; wet moss seep, Antler Creek, 1585 m, 62°25.78′ N 142°22.11′ W, *K.A. Beck 95-200*, 27 June 1995. ST. ELIAS MOUNTAINS: rare in moist bare organic soil of solifluction lobes, limestone ridge between Dan & Copper Creeks, 1554 m, 61°21.56′ N 142°26.43′ W, *M. Cook 94292*, 14 July 1994; scattered in wet seep, Mt. Chitina, 2073 m, 60°57.74′ N 141°17.33′ W, *M. Cook 95225*, 14 July 1995. WRANGELL MOUNTAINS: alpine basin, northwest flank of Mt. Drum, 1615 m, 62°4.5′ N 144°45.91′ W, *C.R. Meyers 84-29*, 4 July 1984; sedge tundra frost boil, Cheshnina Plateau, 1640 m, 61°50.33′ N 144°22.5′ W, *M. Duffy 91088*, 21 July 1991; common in mesic situations, Cone Ridge, 2073 m, 62°8.21′ N 143°18.47′ W, *C. Roland 94-306*, *M. Cook 94362*, 25 July 1994; occasional in bare sandy gravel, Chetaslina Plateau, 1615 m, 61°56.51′ N 144°25.93′ W, *M. Cook 94475*, 15 August 1994; common in stony streambed, Jaegar Mesa, 1893 m, 62°15.9′ N 143°1.24′ W, *C. Roland 95-107*, 30 June 1995; patchy in wet moss, Crystalline Hills, 1585 m, 61°23.59′ N 143°31.85′ W, *M. Cook 95263*, 17 July 1995, *C. Roland 95-243*, 18 July 1995; alluvial fan of seep, streambed & sorted rocks, Lakes Plateau, 1890 m, 62°4.4′ N 143°23.5′ W, *A. Leggett 95-092, 95-091, 95-079, 95-085, 95-103*, 28 & 30 July 1995; scattered in loose, moist limestone gravel on N-facing slopes, Iron Mountain, 1868 m, 61°37.85′ N 144°1.01′ W, *C. Roland 96-578*, *M. Cook 96455*, 16 July 1996; scattered in clay soil on east facing slope, Grotto Creek, 1847 m, 61°30.56′ N 142°24.79′ W, *C. Roland 96-649A*, 23 July 1996; moist muddy scree, Nikolai Mine, 1695 m, 61°27′ N 142°39′ W, *Batten & Barker 96-095*, 27 July 1996 (ALA); rare in snowbed areas, upper Dadina River, 1646 m, 62°3.88′ N 144°35.76′ W, *C. Roland 96-371*, 5 July 1996; occasional in protected chute, limestone ridge southwest of Alice Peak, 1628 m, 61°39.82′ N 144°7.76′ W, *C. Roland 96-388*, 5 July 1996; occasional in mesic volcanic gravel stringers, Hasen Creek, 1835 m, 61°34.06′ N 142°18.33′ W, *M. Cook 96494*, 7 July 1996; occasional in moss on limestone outcrops, Lakina Glacier, 1219 m, 61°33.64′ N 143°19.01′ W, *M. Cook 96538*, 7 July 1996; moist silt adjacent to creek, Nikolai Pass, 1280 m, 61°26′ N 142°40′ W, *Batten & Barker 96-045*, 7 July 1996 (ALA).

This Alaska-Yukon endemic with a Pacific Coastal distribution was known previously from only two localities in the Park: Chitistone Pass (61°37′ N 141°58′ W, *D. F. Murray 1041* (CAN) (Murray 1968)) and Bonanza Ridge (61°30′ N 142°51′ W, *Nordell & Schmitt 163* (LD & ALA) (Nordell and Schmitt 1978)). As indicated by the above collections, this species is now known from throughout the mountain ranges in the Park where it is locally common in alpine mesic sites. Collections from the western Wrangells and the Mentasta Mountains are up to 150 km distant from prior Park collections, and the closest station to the specimens cited above is 78 km to the southwest at Thompson Pass (Valdez Quad: 61°08.0′ N 145°45.0′ W, *C.L. Parker 2415*, 22 July 1990 (ALA)). Map 109.

Arabis calderi G. A. Mulligan (*Arabis lyallii* sensu Hultén (1968) pro parte), Calder's Rockcress — ST. ELIAS MOUNTAINS: scattered in meadow adjacent to sheep trail and in open soil on S-facing slopes, ridge between Logan and Walsh Glaciers, 1951 m, 60°53.94′ N 141°6.75′ W, *C. Roland 95-169*, *M. Cook 95215*, 12 & 13 July 1995.

This North American cordilleran species is new to the flora of Alaska. The western limit of its distribution is represented by the above collection, the closest station being 172 km to the east in the Yukon Territory (Cody 1996). Its distribution to the south and east of the Yukon Territory is spotty, ranging from Great Bear Lake of the Mackenzie District in the Northwest Territories (1108 km distant), to the southwest corner of Alberta and British Columbia (1654 km distant), south to Washington, California and Montana (Mulligan 1995; Cody 1996). It is rare in Alaska (G3G4 S1) and Cody et al. (1998) suggest that it be added to the list of rare species in the Yukon Territory. Map 110.

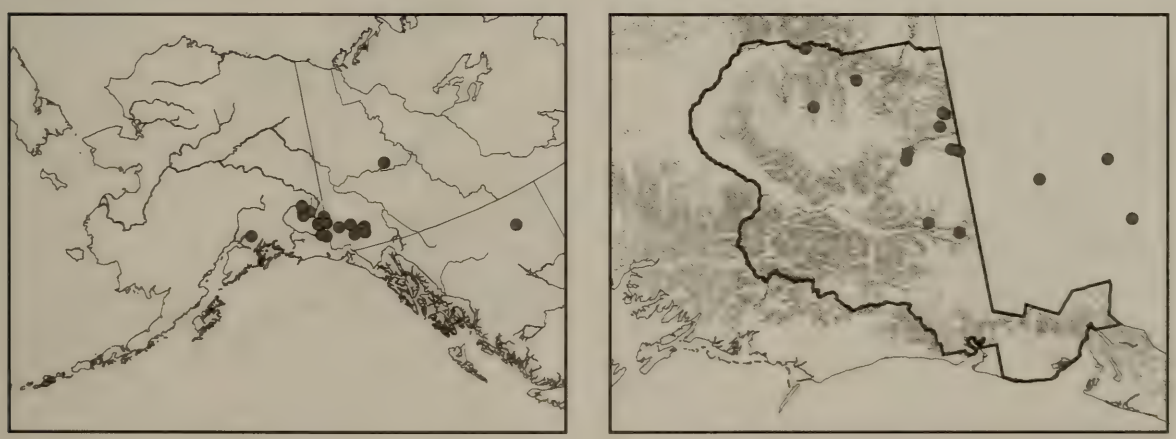
Arabis codyi G.A. Mulligan, Cody's Rockcress — CHUGACH MOUNTAINS: rare on W-facing unstable limestone scree, Granite Range, 1798 m, 61°1′ N 141°53.18′ W, *M. Cook 94441*, 5 August 1994.

This Rockcress, which is new to Alaska, was known from only two localities prior to our collection in the Chugach Mountains: the holotype 230 km to the east in the St. Elias Mountains, Yukon Territory (*D.F. & B. Murray 72*, 1 July 1965 (DAO)) and a specimen from British Columbia 1174 km to the southeast (Perow, 54 30′N, 126 26′W, *Taylor & Levis 468* (UBC) (Mulligan 1995)). This species is considered rare in Alaska (G1G2 S1) and should be added to the list of rare species in the Yukon Territory (Cody et al. 1998). Map 111.

Arabis drepanoloba Greene (*Arabis lemmonii* S. Wats. var. *drepanoloba* (E.L. Greene) Rollins), Rockcress — CHUGACH MOUNTAINS: few in gravel scree between limestone outcrops, ridge above

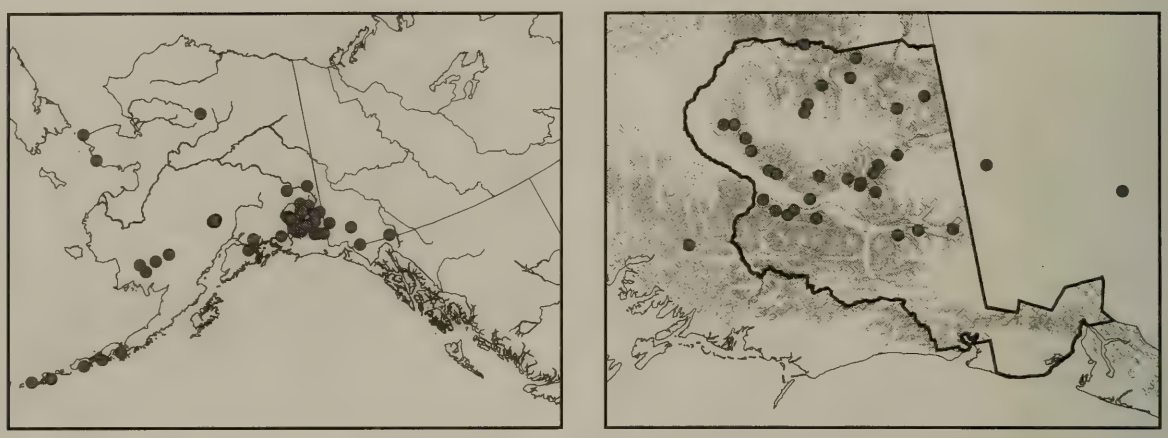
105. Ranunculus trichophyllus var. *eradicatus*

106. Papaver alboroseum

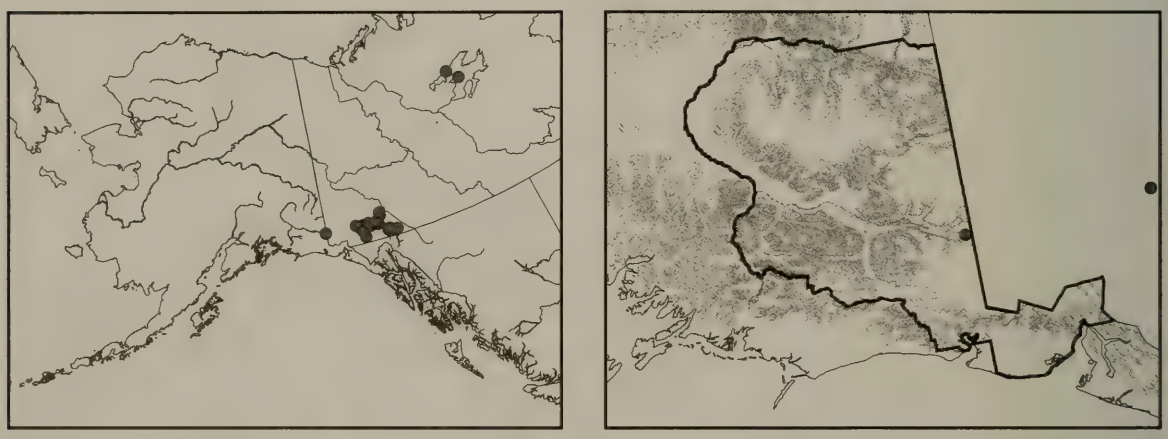


107. Papaver radicatum ssp. *kluanense*

108. Papaver walpolei

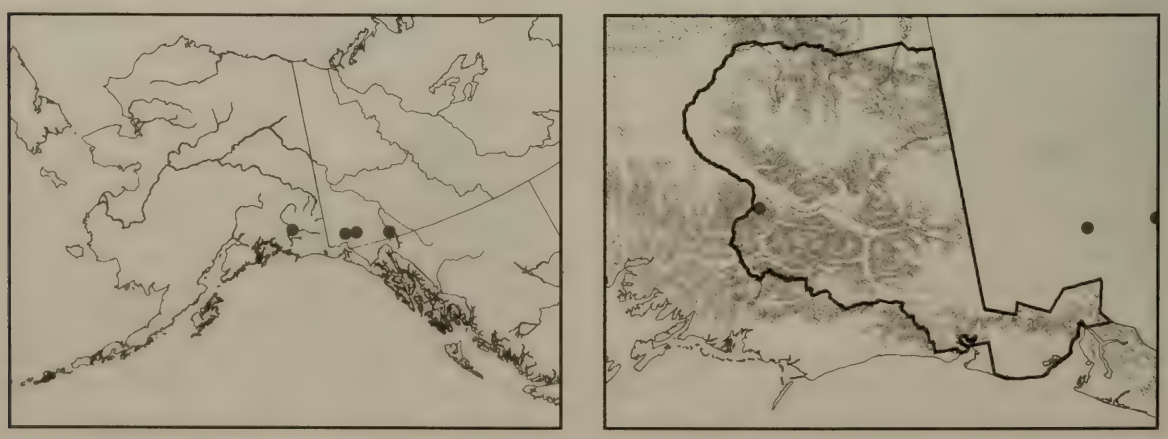


109. Aphragmus eschscholtzianus



110. Arabis calderi

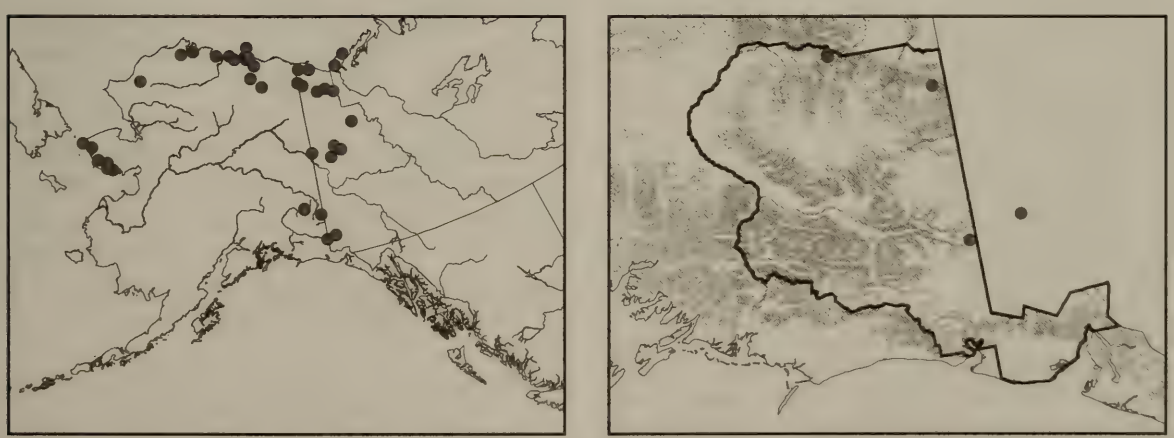
111. Arabis codyi



112. Arabis drepanoloba

113. Arabis lemmonii

114. Arabis media



115. Braya glabella ssp. *glabella*

116. Braya glabella ssp. *purpurascens*

Canyon Creek, 1682 m, 61°24.28′ N 144°21.61′ W, *Cook & Losso 96325*, 7 July 1996 (ALA).

This North American cordilleran Rockcress is also new to the flora of Alaska. The locality cited above, the western limit of its distribution, is 290 km west of a station in the Yukon Territory (Cody 1996). These populations are disjunct from the main range in southeast British Columbia, Alberta, Colorado, Wyoming and Montana (Cody 1996, Mulligan 1995). It is rare in Alaska (G5 S1) and should be added to the list of rare species of the Yukon Territory (Cody 1996). Map 112.

Arabis lemmonii S. Wats., Lemmon's Rockcress — CHUGACH MOUNTAINS: mesic shrub birch-ericaceous scrub, Granite Creek, Granite Range, 701 m, 60°43.78′ N 142°31.4′ W, *Duffy & Barnes 96-064*, 8 August 1996 (ALA), confirmed by G. A. Mulligan (DAO) 1998.

Another North America cordilleran Rockcress new to the flora of Alaska and with the western limit of its range in the Park. This species is also rare in Alaska (G5 S1) and in the Yukon Territory (Douglas et al. 1981). The specimen cited above is 116 km west of the Yukon Territory collection near Kluane Lake (Cody 1996). The stations in Alaska and the Yukon are disjunct from the main range of this species in southwestern Alberta, southern British Columbia, Montana, Idaho, Washington, Wyoming, Colorado, Utah, Nevada, Oregon and California (Mulligan 1995). Map 113.

Arabis media N. Busch (*Arabis arenicola* (Richardson ex Hook.) Galert var. *pubescens* S. Wats. pro parte), Rockcress — WRANGELL MOUNTAINS: scattered in loose gravel and sparse tundra on SW-facing slope, vic. Snyder Peak, 1524 m, 62°4.47′ N 144°30.51′ W, *C. Roland 96-383*, 5 July 1996; occasional in moist sandy soil, vic. Long Glacier, 1399 m, 61°48.04′ N 144°6.27′ W, *M. Cook 96709*, 8 August 1996 (ALA); scattered in *Rhacomitrium* moss on gravel bar, upper Copper River, 945 m, 62°19.02′ N 143°47.44′ W, *M. Cook 96719*, 8 August 1996.

This amphiberingean arctic-alpine Rockcress was known previously from the vicinity of Guerin Glacier in the St. Elias Mountains (*D. F. Murray 2022*, 3 August 1968 (ALA)). The stations cited above extend the range 156 km west into the Wrangell Mountains. These southcentral Alaska collections are 913 km southeast of stations in western Alaska and 821 km south of stations along the arctic coast of the Yukon Territory (Cody 1996, Hultén 1968). This species should be added to the list of rare plants of the Yukon Territory (Cody 1996). Map 114.

Braya glabella Richardson ssp. *glabella*, Braya, Smooth Northern Rockcress — MENTASTA MOUNTAINS: rare in moist bare soil on limestone ledge above Soda Lake, 1173 m, 62°32.36′ N 142°53.98′ W, *M. Cook 94309*, 21 July 1994; rare in limestone gravels, ridge between Soda and Platinum Creeks, 1494 m, 62°31.2′ N 142°54.03′ W, *C. Roland 95-134*, 5 July 1995; rare in red colored calcareous gravel on ridge above limestone outcrops, Baultoff Creek, 1707 m, 62°9.13′ N 141°14.51′ W, *M. Cook 94181*, 27 June 1994; ST. ELIAS MOUNTAINS: barren scree slope, ridge between Logan and Walsh Glaciers, 1951 m, 60°53.94′ N 141°6.75′ W, *M. Cook 95205*, 11 July 1995.

This North American arctic-alpine mustard is rare in the Yukon Territory (Douglas et al. 1981). The specimens cited above extend its range 310 km south from Charley River Quad (Upper Hard Luck and Cathedral Creek, 65°09.0′ N 141°03.0′ W, *Parker & Hasselbach 6340*, 23 June 1996 (ALA)) and connect the range 54 km to the east in the Yukon Territory (Cody 1996). Map 115.

Braya glabella Richardson ssp. *purpurascens* (R. Br.) Cody (*Braya purpurascens* (R. Br.) Bunge), Purplish Braya — CHUGACH MOUNTAINS: rare on W-facing limestone scree slope & in *Dryas* dwarf scrub tundra, ridge between Iron and Lime Creeks, 1798 m, 61°1′ N 141°53.18′ W, *M. Cook 94435*, *94445B*, 6 August 1994. WRANGELL MOUNTAINS: rare on boulder slope, Rambler Mine, 1219 m, 62°21.92′ N 143°2.87′ W, *M. Cook 8979*, 9 June 1989.

The southern limit of this circumpolar arctic-alpine mustard is documented by the above localities. These collections extend the range 242 km southeast into the Chugach and Wrangell Mountains from the Alaska Range (Healy Quad: Dry Creek, 63°51.0′ N 147°30.0′ W, *Viereck & Jones 5953*, 23 July 1962 (ALA)) and connect the range 250 km to the east in the Yukon Territory (Cody 1996). This species is rare in the Yukon Territory (Douglas et al. 1981). Map 116.

Draba cinerea Adams, Grayleaf Whitlowgrass — MENTASTA MOUNTAINS: barren, gravel scree slope on limestone ridge between Lost and Platinum Creeks, 1646 m, 62°34.58′ N 143°5.58′ W, *M. Cook 94329A*, 23 July 1994. ST. ELIAS MOUNTAINS: scattered on loose, disturbed, S-facing marble scree slope between Logan and Walsh Glaciers, 1951 m, 60°53.94′ N 141°6.75′ W, *C. Roland 95-148*, 11 July 1995. WRANGELL MOUNTAINS: rare under boulder on basalt tuff and rubble slope, Cone Ridge, 2073 m, 62°8.21′ N 143°18.47′ W, *M. Cook 94396*, 25 July 1994.

This species is circumpolar with an arctic-alpine distribution. It was collected adjacent to the Park in 1981 at the confluence of the Chitina and Copper Rivers (*D. F. Murray 6194* (ALA)) which is 79 km south of the specimen cited above from Cone Ridge and 190 km west of the station in the St. Elias Mountains. These collections in southcentral Alaska are 804 km disjunct from the main range of the species in arctic Alaska (Demarcation Point Quad: Nuvagapak Pt., 69°53.0′ N 142°18.0′ W, *C.R. Meyers 80-14*, 20 July 1980 (ALA)) and 634 km northeast of a collection in the Mt. Katmai Quad (Coville Lake, 58°45.0′ N 155°37.0′ W, *G. Schaller s.n.*, 8 July 1954 (ALA)). Map 117.

Draba corymbosa R. Br. ex DC. (*D. macrocarpa* Adams), Flattop Whitlowgrass — CHUGACH MOUNTAINS: occasional in mossy streamside tundra on SE-facing slope, Verde Ridge, 1554 m, 61°14.03′ N 143°28.52′ W, *Roland & D'Auria 96-476*, 11 July 1996; occasional in moist calcareous gravel in pro-

tected area on north side of ridge, Granite Creek, 1829 m, 61°0.22′ N 141°51.1′ W, *C. Roland 96-741B*, 28 July 1996; W-facing rocky tundra slope, East Fork Kiagna River, 1487 m, 60°59.5′ N 142°1′ W, *Batten & Barker 96-326C*, 29 July 1996; occasional on barren limestone shale at summit of plateau, Bridge Creek, 1871 m, 61°20.41′ N 144°6.97′ W, *M. Cook 96489*, 7 July 1996. WRANGELL MOUNTAINS: rare in rocks on S-facing slope, Jaegar Mesa, 1893 m, 62°15.9′ N 143°1.24′ W, *C. Roland 95-117C*, 1 July 1995; Lakes Plateau, 1890 m, 62°4.4′ N 143°23.5′ W, *A. Leggett 95-083*, 30 July 1995; moist clay gravel flats, Nikolai Mine, 1695 m, 61°27′ N 142°39′ W, *Batten & Barker 96-090*, 24 July 1996 (ALA); steep W-SW-facing limestone scree, Chitistone Mountain, 1219 m, 61°28′ N 142°33′ W, *Batten & Barker 96-149A*, 26 July 1996 (ALA).

This mustard is circumpolar with an arctic-alpine distribution. The stations cited above are 247 km southeast of stations in the Alaska Range (Hultén 1968) and 156 km west of stations in the Yukon Territory where it is widely distributed throughout the mountains (Cody 1996). Map 118.

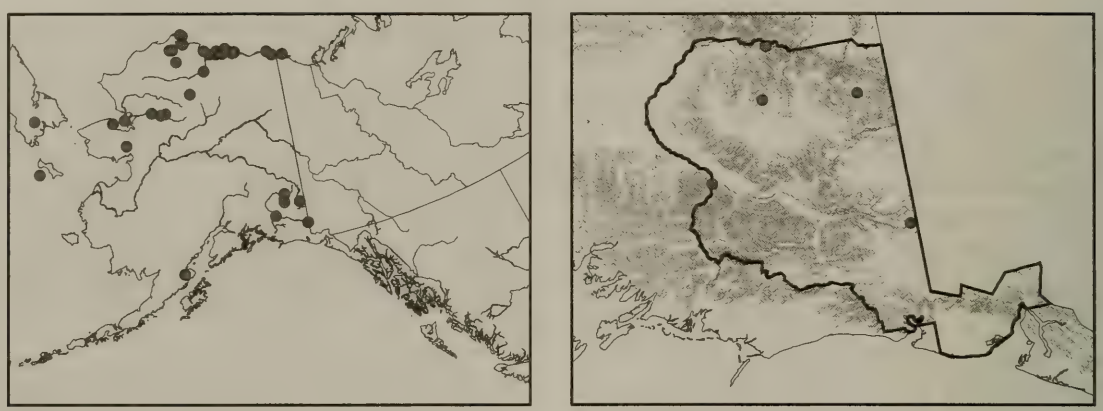
Draba crassifolia Graham, Snowbed Whitlowgrass — CHUGACH MOUNTAINS: Iron Creek, limestone unit between Iron & Lime Creeks, S of Chitina River, Granite Range, 1798 m, 61°1′ N 141°53.18′ W, *M. Cook 94433*, 6 August 1994; boulder field on W-facing slope, Goat Creek, 1487 m, 60°59.5′ N 142°1′ W, *Batten & Barker 96-328A*, 29 July 1996 (ALA); scattered in granite gravel on ridge, West Fork Goat Creek, 1487 m, 60°59.8′ N 142°11.8′ W, *M. Cook 96654B*, 31 July 1996; few in bare mineral soil between gravel and cobble of rock outcrops, Nelson Mountain, 1558 m, 61°19.37′ N 143°48.83′ W, *M. Cook 96376*, 7 July 1996. MENTASTA MOUNTAINS: ridge east of Soda Lake, 1173 m, 62°32.36′ N 142°53.98′ W, *C. Roland 94-241*, 21 July 1994; unstable, nearly bare sandy area in limestone scree, Lost Creek, 1646 m, 62°34.58′ N 143°5.58′ W, *C. Roland 94-267*, 23 July 1994. NUTZOTIN MOUNTAINS: exposed NW-facing talus slope, vic. peak 5745, Gold Hill, 1585 m, 62°4.05′ N 141°52′ W, *M. Cook 92071*, 27 June 1992; cutbank below sloughing *Cassiope* heath, Wiki Creek, 1411 m, 61°54.46′ N 141°10.68′ W, *M. Cook 96086*, 10 June 1996. ST. ELIAS MOUNTAINS: rare in mesic, protected area on north side of small rock outcrop, ridge between Logan and Walsh Glaciers, 1951 m, 60°53.94′ N 141°6.75′ W, *C. Roland 95-160*, 12 July 1995; occasional in mixed soil and gravel of forb herbaceous community, Mt. Chitina, 2073 m, 60°57.74′ N 141°17.33′ W, *C. Roland 95-196, 95-2015A*, *M. Cook 95240*, 14 & 15 July 1995. WRANGELL MOUNTAINS: N and E-facing scree slope, Lime Creek ridge, 1935 m, 61°28.41′ N 141°30.7′ W, *M. Cook 92509A*, 9 July 1992; uncommon, in heavily grazed sheep-bed area of turfy graminoid-forb tundra, Lime Creek ridge, 1646 m, 61°46.25′ N 141°50.36′ W, *C. Roland 94-102*, 21 June 1994; open soil in tundra, Crystalline Hills, 1585 m, 61°23.59′ N 143°31.85′ W, *C. Roland 95-232B*, 18 July 1995; occasional in moss of wet seep, Hasen Creek, 1835 m, 61°34.06′ N 142°18.33′ W, *M. Cook 96497*, 7 July 1996. NUTZOTIN MOUNTAINS: rockfield, ridge 2.8 km W of Ophir Creek, 1966 m, 61°56.1′ N 141°35.68′ W, *M. Duffy 92172*, 8 July 1992.

This amphiatlantic mustard with an arctic-alpine distribution was previously known from Skolai-Chitistone Pass in the Wrangell Mountains (61°37.0′ N 141°58.0′ W, *D. F. Murray 724*, 1966 (ALA) & 61°37′ N 142°3′ W, *R. Scott s.n.* (MICH)). It is now known throughout the alpine regions of the Park. The collections cited above connect its distribution 100 km to the northwest in the Alaska Range with its range 71 km to the east in the Yukon Territory (Cody 1996) where it was considered rare (Douglas et al. 1981). Map 119.

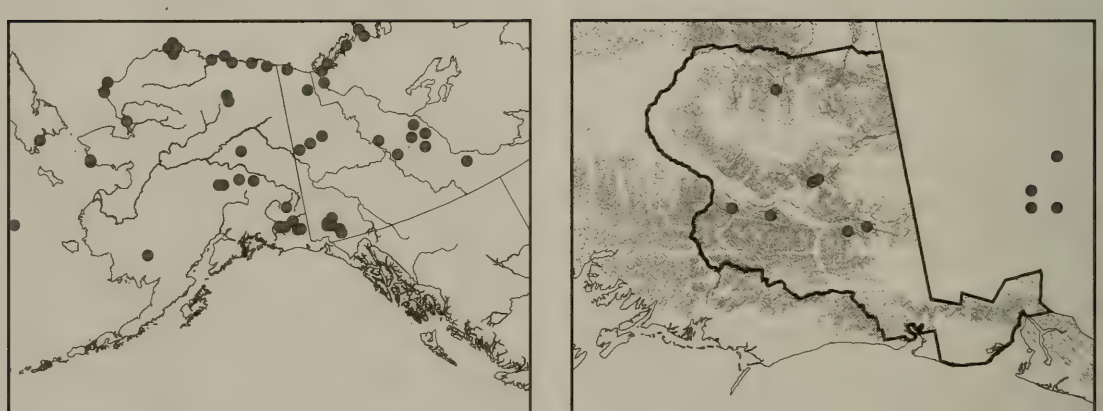
Draba densifolia Nutt. ex Torrey & A. Gray, Denseleaf Whitlowgrass — NUTZOTIN MOUNTAINS: rockfield, Ophir Creek, 1966 m, 61°56.1′ N 141°35.68′ W, *M. Duffy 92172*, 8 July 1992.

This North American cordilleran mustard is disjunct in Alaska from southern British Columiba, California, Oregon, Idaho, Montana, Wyoming and Utah. The collection cited above from the Nutzotin Mountains is one of only seven localities in Alaska, the closest being 405 km to the northeast at Cantwell (*A.E. & R.T. Porsild 61*, 8 June 1926 (CAN, S) (Hultén 1941-1950)). It is rare in Alaska (G5 S1) and in the Yukon Territory where it is known in the Tombstone region of the Ogilvie Mountains (Cody 2000). Map 120.

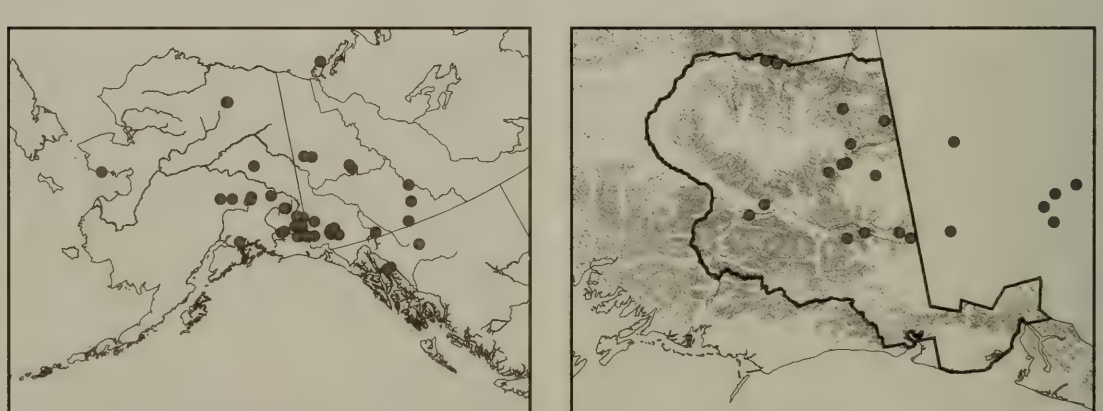
Draba incerta Payson, Yellowstone Whitlowgrass — CHUGACH MOUNTAINS: graminoid forb herbaceous meadow, Iron Creek, 1798 m, 61°1′ N 141°53.18′ W, *M. Cook 94442*, 5 August 1994; rare in old slide debris, Amy Creek, 1164 m, 61°4.01′ N 143°34.83′ W, *C. Roland 96-531*, 13 July 1996; few in unstable limestone scree, Canyon Creek, 1682 m, 61°24.28′ N 144°21.61′ W, *Cook & Losso 96326*, 7 July 1996; few in bare mineral soil, Nelson Mountain, 1558 m, 61°19.37′ N 143°48.83′ W, *M. Cook 96377*, 7 July 1996; scattered in granitic rubble on S-facing slope, Nerelna Creek Plateau, 1372 m, 61°26.66′ N 144°17.69′ W, *Roland & D'Auria 96-410*, 8 July 1996; rock outcrops, Towhead Mountain, 1433 m, 61°3.21′ N 142°39.8′ W, *Duffy & Barnes 96-156*, 8 August 1996. MENTASTA MOUNTAINS: *Dryas*-rock tundra, Lost Basin, 1722 m, 62°36.45′ N 143°12.03′ W, *M. Cook 95170*, 7 July 1995. ST. ELIAS MOUNTAINS: rare in mesic area on small rock outcrop, ridge between Logan and Walsh Glaciers, 1951 m, 60°53.94′ N 141°6.75′ W, *C. Roland 95-159*, 12 July 1995; rock crevices of S-facing outcrop, Mt. Chitina, 2073 m, 60°57.74′ N 141°17.33′ W, *M. Cook 95235*, *C. Roland 95-201, 95-202, 95-206*, 15 July 1995; N-facing scree, Nikolai Pass, 1280 m, 61°26′ N 142°40′ W, *Batten & Barker 96-016B*, 23 July 1996. WRANGELL MOUNTAINS: scattered on barren slope, Grotto Creek, 1847 m, 61°30.56′ N 142°24.79′ W, *C. Roland 96-651*, 23 July 1996.



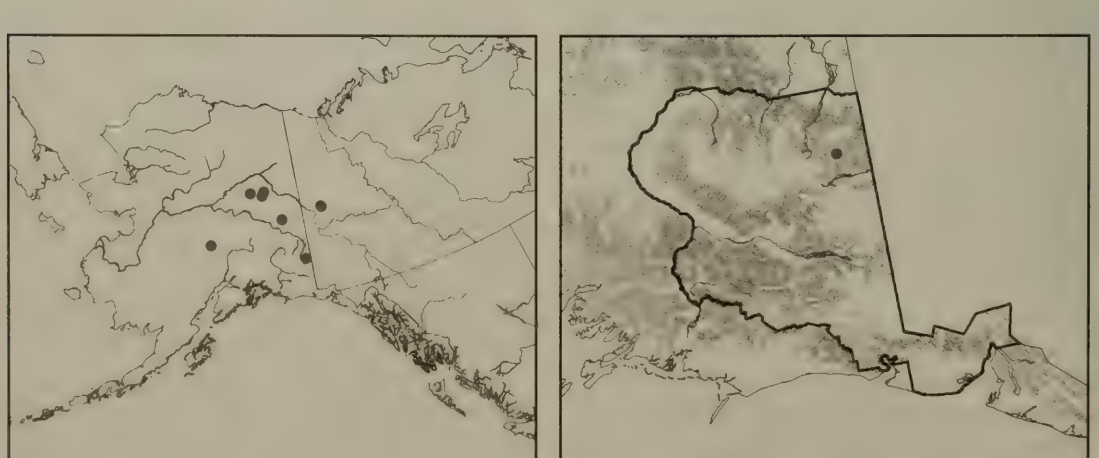
117. Draba cinerea



118. Draba corymbosa



119. Draba crassifolia



120. Draba densifolia

121. Draba incerta

122. Draba kananaskis

123. Draba lactea

124. Draba lonchocarpa var. *thompsonii*

This North American cordilleran mustard is rare in Alaska (G5 S2S3). The localities cited above connect its range 204 km to the west in the Anchorage Quad (Mi 119 Seward Highway, 61°07.0′ N 149°52.0′ W, *C. L. Parker 6953*, 20 May 1997 (ALA)) with its distribution 88 km to the east in the Yukon Territory (Cody 1996). Map 121.

Draba kananaskis G.A. Mulligan, Longstalk Whitlowgrass — CHUGACH MOUNTAINS: scattered in seeps on E-facing slope, Verde Ridge, 1554 m, 61°14.03′ N 143°28.52′ W, *Roland & D'Auria 96-479*, 11 July 1996; occasional in moist calcareous gravel, Granite Creek, 1829 m, 61°0.22′ N 141°51.1′ W, *C. Roland 96-740, 96-741A*, 28 July 1996.

This North American cordilleran mustard was known only from the vicinity of Hope on the Kenai Peninsula (Hultén 1968). The two localities cited above from the Chugach Mountains are 318 km east of the Kenai Peninsula locality. Map 122.

Draba lactea Adams — CHUGACH MOUNTAINS: rare on W-facing unstable scree slope, Iron Creek, 1798 m, 61°1′ N 141°53.18′ W, *M. Cook 94445C*, 6 August 1994. MENTASTA MOUNTAINS: scattered on N-facing limestone ledge in sheep bed, Lost Basin, 1722 m, 62°36.45′ N 143°12.03′ W, *M. Cook 95168*, 4 July 1995; scattered over sparsely vegetated dry forb herbaceous rubble slope, Lost Basin, 1722 m, 62°36.45′ N 143°12.03′ W, *M. Cook 95173*, 4 July 1995. NUTZOTIN MOUNTAINS: few on S-facing red basalt rubble slope, Wiki Creek, 1411 m, 61°54.46′ N 141°10.68′ W, *M. Cook 96091*, 10 June 1996. WRANGELL MOUNTAINS: polygon tundra, Lakes Plateau, 1890 m, 62°4.4′ N 143°23.5′ W, *M. Potkin 95-069*, 29 July 1995; scattered in moist limestone, Iron Mountain, 1868 m, 61°37.85′ N 144°1.01′ W, *C. Roland 96-573, 96-576*, 16 July 1996; N-facing scree, Nikolai Pass, 1280 m, 61°26′ N 142°40′ W, *Batten & Barker 96-016C*, 23 July 1996 (ALA); scattered in loose limestone cobbles on steep, SE-facing slope, Alice Peak, 1628 m, 61°39.82′ N 144°7.76′ W, *C. Roland 96-390, 96-391, 96-395*, 5 July 1996.

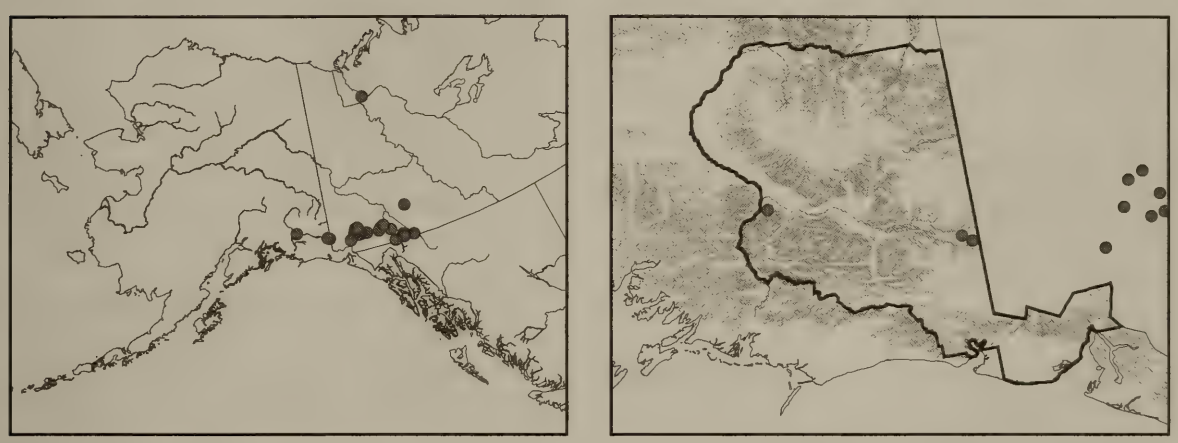
This circumpolar arctic-alpine mustard was known from one locality in the Wrangell Mountains (Chitistone Pass, 61°37′ N 142°3′ W, *R. Scott s.n.*, 1967 (MICH) (Scott 1968); 61°37′ N 141°58′ W, *D. F. Murray 1052, 1053*, 21 July 1967 (CAN) (Murray 1968)). The specimens cited above extend the range 114 km west in the Wrangell Mountains and 125 km north into the Mentasta Mountains. These collections connect the range 122 km north in the Alaska Range (Mt Hayes Quad: 63°28.0′ N 145°49.0′ W, *Batten et al. 78-67*, 30 June 1978 (ALA)) with the distribution 114 km to the east in the Yukon Territory (Cody 1996). Map123 .

Draba lonchocarpa Rydb. var. *thompsonii* (C.L. Hitchc.) Rollins — MENTASTA MOUNTAINS: scattered at base of scree slope below limestone ridge, headwaters of Lost Creek, 1722 m, 62°36.45′ N 143°12.03′ W, *M. Cook 95184*, 11 July 1995.

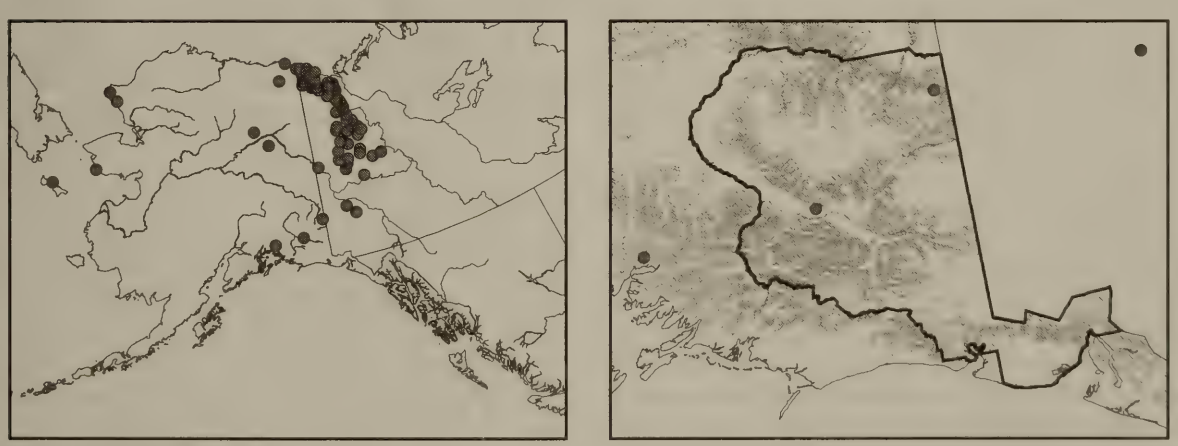
This specimen documents the northern and western limit of the range of this North American cordilleran mustard, the only known locality of this variety in Alaska. It is 1100 km disjunct from the mountains of British Columbia and western Washington (Rollins 1993 and Mulligan 1974). Map 124.

Draba macounii O.E. Schulz — MENTASTA MOUNTAINS: rare in bare mineral soil on S-facing limestone talus slope, Soda Lake, 1173 m, 62°32.36′ N 142°53.98′ W, *M. Cook 94312A*, 22 July 1994; rare in red thin-bedded limestone scree, ridge between Lost and Platinum Creeks at peak 5240, 1646 m, 62°34.58′ N 143°5.58′ W, *M. Cook 94341B*, 23 July 1994; rare in bare argillite gravels and rock crevices on windswept ridge, ridge between Little Jack and Trail Creeks, 1615 m, 62°36.05′ N 143°17.63′ W, *C. Roland 95-021*, 7 June 1995; saddle near contact of limestone and Nikolai Greenstone, ridge between Little Jack and Trail Creeks, 1615 m, 62°36.05′ N 143°17.63′ W, *M. Potkin 95-56B*, 7 June 1995; upper Trail Creek, 1341 m, 62°37.09′ N 143°16.06′ W, *Potkin & Leggett 95-044*, 27 July 1995; limestone talus, headwaters of Lost Creek, 1722 m, 62°36.45′ N 143°12.03′ W, *K.A. Beck 95-221*, 4 July 1995; scattered in gravel around outcrop on limestone ridge, between Soda and Platinum Creeks, 1494 m, 62°31.2′ N 142°54.03′ W, *C. Roland 95-145*, 6 July 1995. NUTZOTIN MOUNTAINS: *Dryas* tundra, ridge between Fogenbera Pass and Shotgold Creek, 1783 m, 61°53.28′ N 141°37.1′ W, *M. Cook 92458*, 8 June 1992. ST. ELIAS MOUNTAINS: occasional in dwarf scrub/herbaceous meadow tundra, N-facing rock ledges and S-facing bare solifluction lobes, ridge between Dan & Copper Creeks, 1554 m, 61°21.56′ N 142°26.43′ W, *M. Cook 94286A*, 13 July 1994; rare in bare moist organic soil on S-facing limestone outcrop, ridge between Dan & Copper Creeks, 1554 m, 61°21.56′ N 142°26.43′ W, *M. Cook 94296A*, 14 July 1994; occasional on vegetated stringer of limestone talus slope, ridge between Logan and Walsh Glaciers, 1951 m, 60°53.94′ N 141°6.75′ W, *M. Cook 95200*, 11 July 1995; mixed soil and rubble in debris flow on W-facing slope, ridge between Logan and Walsh Glaciers, 1951 m, 60°53.94′ N 141°6.75′ W, *C. Roland 95-153*, 11 July 1995. WRANGELL MOUNTAINS: alpine tundra, 152 m above and E of Nabesna Glacier moraine, 1768 m, 61°56.6′ N 143° W, *M. Cook 9267*, 26 June 1992; scree slope, N and E-facing, ridge between Lime Creek and Solo Flats, 1935 m, 61°28.41′ N 141°30.7′ W, *M. Cook 92505, 92510*, 8 July 1992; seep area in talus, Jaegar Mesa, 1893 m, 62°15.9′ N 143°1.24′ W, *Moran & Roland 95-30*, 30 June 1995; occasional in solifluction soil below ridge, Crystalline Hills, 1585 m, 61°23.59′ N 143°31.85′ W, *M. Cook 95268*, 18 July 1995; occasional on barren NE-facing slope of fine gravelly scree, Crystalline Hills, 1585 m, 61°23.59′ N 143°31.85′ W, *C. Roland 95-245B*, 18 July 1995; Lakes Plateau,

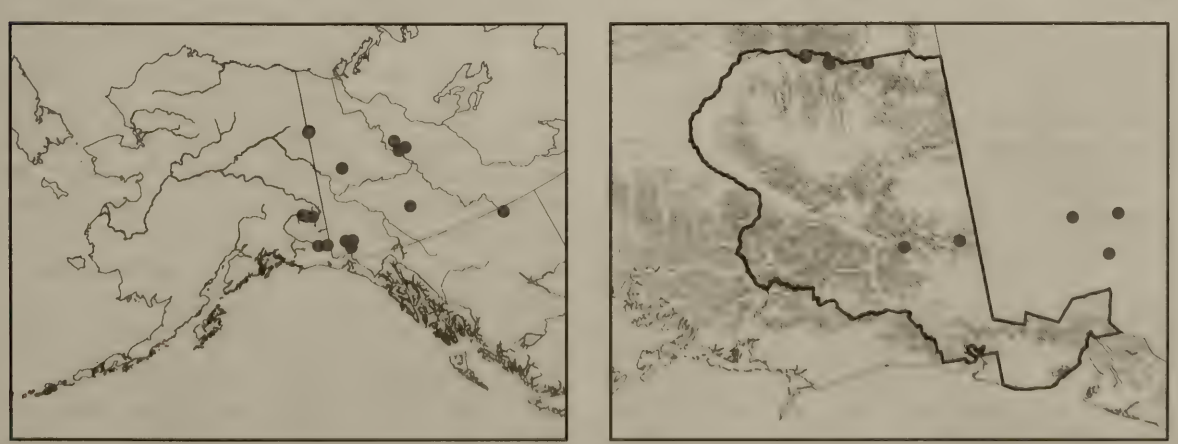
125. Draba macounii



126. Draba oligosperma



127. Draba palanderiana



128. Draba porsildii

1890 m, 62°4.4′ N 143°23.5′ W, *M. Potkin 95-095A*, 30 July 1995; scattered in barren limestone gravel on SW-facing slope, Iron Mountain, 1868 m, 61°37.85′ N 144°1.01′ W, *C. Roland 96-580*, 16 July 1996; scattered in barren gravel on S-facing ridge, ridge W of Grotto Creek headwaters, 1847 m, 61°30.56′ N 142°24.79′ W, *C. Roland 96-649B*, 23 July 1996; occasional in moist volcanic gravel scree, Iron Mountain, 1868 m, 61°37.85′ N 144°1.01′ W, *M. Cook 96461*, 7 July 1996; few on saddle in gravel and patchy alpine forb herbaceous vegetation, between headwaters of King and Pouch Creeks, 1926 m, 61°38.99′ N 144°3.51′ W, *M. Cook 96469*, 7 July 1996; few in gravel scree on sparsely vegetated NE-facing slope, alpine lake basin on limestone, E side of Lakina Glacier, 1219 m, 61°33.64′ N 143°19.01′ W, *M. Cook 96547*, 7 July 1996.

This North American cordilleran mustard has a spotty distribution from Alaska south to Colorado and Montana. The specimens cited above from all of the mountains in the Park connect its range 227 km to the northwest in the Alaska Range (Healy Quad: Dry Creek, 63°52.0′ N 147°30.0′ W, *Viereck & Jones 5962*, 23 July 1962 (ALA)) with the distribution 80 km to the southeast in the Yukon Territory (Cody 1996). Map 125.

Draba oligosperma Hook., Fewseed Whitlowgrass — CHUGACH MOUNTAINS: occasional in marble rubble on steep and dry SE-facing slope, ridge between Canyon and Pass Creeks, 1463 m, 61°24.35′ N 144°20.8′ W, *Roland & D'Auria 96-436*, 9 July 1996. ST. ELIAS MOUNTAINS: common in dry gravels on S-facing slope with sagebrush-forb vegetation, ridge between Logan and Walsh Glaciers, 1951 m, 60°53.94′ N 141°6.75′ W, *C. Roland 95-175A*, 12 July 1995, *M. Cook 95212, 95213*, 13 July 1995.

This North America cordilleran mustard was collected by H. M. Laing in 1925 on the upper Chitina River most likely in the vicinity of our collection from the St. Elias Mountains (Porsild 1939; Hultén 1941-1950). The other station in Alaska is our collection in the Chugach Mountains 182 km to the east. The stations on the upper Chitina River are 121 km west of the closest localities in the Yukon Territory and are disjunct from the main cordilleran range of the species in Colorado, California and Washington (Rollins 1993). Map 126.

Draba palanderiana Kjellman., Palander's Whitlow-Grass — NUTZOTIN MOUNTAINS: occasional on S-facing limestone outcrops, Baultoff Creek, 1707 m, 62°9.13′ N 141°14.51′ W, *M. Cook 94180*, 27 June 1994. WRANGELL MOUNTAINS: moist gravel on scree slope, in tuft of *Erigeron purpuratus*, 1585 m, 61°23.59′ N 143°31.85′ W, *M. Cook 95267*, 18 July 1995.

This mustard is an Alaska-Yukon endemic with an arctic-alpine distribution and is rare in Alaska (G4G5 S4). The localities cited above are 159 km northeast of a station near Valdez (Porsild and Cody 1980) and 141 km southwest of a station in the Yukon Territory (Cody 1996). Map 127.

Draba porsildii G. A. Mulligan, Porsild's Whitlowgrass — CHUGACH MOUNTAINS: scree, Goat Creek, Granite Range, 1487 m, 60°59.5′ N 142°1′ W, *Batten & Barker 96-327B*, 29 July 1996 (ALA); few in granite gravel, ridge above W. Fork Goat Creek, 1487 m, 60°59.8′ N 142°11.8′ W, *M. Cook 96661*, 31 July 1996. MENTASTA MOUNTAINS: rare in bare mineral soil on S-facing talus slope, Soda Lake, 1173 m, 62°32.36′ N 142°53.98′ W, *M. Cook 94312B*, 22 July 1994; occasional in gravel areas on limestone outcrop, Trail Creek, 1615 m, 62°36.05′ N 143°17.63′ W, *C. Roland 95-004, 95-015*, 6 & 7 June 1995 (ALA); upper Trail Creek, 1341 m, 62°37.09′ N 143°16.06′ W, *M. Potkin 95-037A*, 27 July 1995; scattered in limestone gravel, Soda Lake ridge, 1494 m, 62°31.2′ N 142°54.03′ W, *C. Roland 95-144*, 7 July 1995 (ALA). NUTZOTIN MOUNTAINS: few in bare mineral soil, ridge at headwaters of Alder Creek, 1554 m, 62°28.44′ N 142°15.06′ W, *M. Cook 95131*, 26 June 1997 (ALA). ST. ELIAS MOUNTAINS: rare in disturbed area, Mt. Chitina, 2073 m, 60°57.74′ N 141°17.33′ W, *C. Roland 95-203*, 15 July 1995.

The seven localities in the Mentasta, Nutzotin and Granite Ranges cited above are the only other stations in Alaska besides those in the Black River Quad 458 km to the north (66°35.0′ N 141°10.0′ W, *R. Lipkin 91-46*, 10 June 1991; 66°36.0′ N 141°11.0′ W, *R. Lipkin 91-96*, 11 June 1991; 66°36.0′ N 141°11.0′ W, *R. Lipkin 91-141*, 14 June 1991; 66°32.0′ N 141°04.0′ W, *R. Lipkin 91-153*, 15 June 1991 (ALA)). Our collections are 101 km west of stations in the Yukon Territory (Cody 1996). This species is a North American cordilleran endemic known from Colorado north to the Northwest Territories, Yukon and Alaska where it is considered rare (Douglas et al. 1981). Map 128.

Draba ruaxes Payson & H. (*D. exalata* Ekman, *D. ventosa* A. Gray var. *ruaxes* (Payson & H. St. John)), Rainier Whitlowgrass — CHUGACH MOUNTAINS: rare in gravel scree, serpentinized ultramafic unit, Granitic Creek ridge, 1768 m, 61°6.19′ N 142°55.03′ W, *M. Cook 94220*, 8 July 1994. MENTASTA MOUNTAINS: rare in moist bare soil on ledge between limestone gravel scree, Soda Lake, 1173 m, 62°32.36′ N 142°53.98′ W, *M. Cook 94311A*, 21 July 1994; occasional on barren gravel scree, Lost Creek, 1646 m, 62°34.58′ N 143°5.58′ W, *M. Cook 94331*, 23 July 1994; scattered in runnels of fine limestone scree near ridge, Trail Creek, 1615 m, 62°36.05′ N 143°17.63′ W, *C. Roland 95-009*, 6 June 1995; occasional in moss betwen limestone rubble on N-facing slope, headwaters of Lost Creek, 1722 m, 62°36.45′ N 143°12.03′ W, *K.A. Beck 95-225, 95-231, 95-241, M. Cook 95175, 95185*, 7 July 1995; common in fine, red calcareous gravel on E-facing slope above Totschunda Creek, 1280 m, 62°27.63′ N 142°12.44′ W, *C. Roland 96-289*, 24 June 1996; few in basalt scree, ridge N of Totschunda Creek mouth, 1494 m, 62°28.28′ N 142°40.5′ W, *Cook & Shea 96285*, 7 July 1996; scattered in unconsolidated limestone and

greenstone rubble, Lost Creek, 1189 m, 62°35′ N 143°9.1′ W, *Roland & D'Auria 97-055*, 26 June 1997. NUTZOTIN MOUNTAINS: gravel soil on ridgetop, Copper Pass, 1943 m, 62°17.16′ N 142°31.44′ W, *J. Bolivar 84-71*, 28 June 1984; occasional in sterile limestone scree, Baultoff Creek, 1707 m, 62°9.13′ N 141°14.51′ W, *C. Roland 94-144A*, 27 June 1994; scattered in exposed NW-facing area of ridge, Baultoff Creek, 1707 m, 62°9.13′ N 141°14.51′ W, *C. Roland 94-161*, 28 June 1994; scattered on limestone ridge in bare mineral soil, Copper Pass, 1942 m, 62°17.16′ N 142°31.44′ W, *M. Cook 94344*, 24 July 1994; scattered on ridge in *Rhacomitrium,* Klein Creek, 1747 m, 62°2.29′ N 141°19.88′ W, *M. Cook 95018*, 15 June 1995; scattered in volcanic rubble, plateau between Bryan and Willow Creeks, 1829 m, 61°58.97′ N 141°50.03′ W, *M. Cook 95086*, 21 June 1995; occasional on steep N-facing slope in fine scree, ridge at headwaters of Alder Creek, 1554 m, 62°28.44′ N 142°15.06′ W, *K.A. Beck 95-215*, 30 June 1995. ST. ELIAS MOUNTAINS: scattered in steep limestone gravel, butte between Dan and Copper Creeks, 1554 m, 61°21.56′ N 142°26.43′ W, *C. Roland 94-230B*, 14 July 1994; scattered on S-facing rock slope Mt. Chitina, 2073 m, 60°57.74′ N 141°17.33′ W, *M. Cook 95231*, 14 July 1995. WRANGELL MOUNTAINS: N-facing limestone talus slope, Lime Creek, 1646 m, 61°46.25′ N 141°50.36′ W, *M. Cook 94118*, 21 June 1994; scattered in frost shattered rocks on limestone ridge, Copper Pass, 1942 m, 62°17.16′ N 142°31.44′ W, *C. Roland 94-283*, 24 July 1994; occasional in moist organic soil betwen basalt tuff fragments, Cone Ridge, 2073 m, 62°8.21′ N 143°18.47′ W, *M. Cook 94371*, 25 July 1994; common in stony areas, Cone Ridge, 2073 m, 62°8.21′ N 143°18.47′ W, *C. Roland 94-311*, 26 July 1994; scattered in moss on stony slopes, Jaegar Mesa, 1893 m, 62°15.9′ N 143°1.24′ W, *Moran & Roland 95-27*, 30 June 1995; rare in moss-lichen dwarf willow tundra, Crystalline Hills, 1585 m, 61°23.59′ N 143°31.85′ W, *M. Cook 95273*, *C. Roland 95-245A*, 18 July 1995; scattered in barren calcareous gravel, Iron Mountain, 1868 m, 61°37.85′ N 144°1.01′ W, *C. Roland 96-568*, 16 July 1996; occasional in gravel and rubble on SE-facing limestone slopes, southwest of Alice Peak, 1628 m, 61°39.82′ N 144°7.76′ W, *C. Roland 96-387*, 5 July 1996.

This mustard was known from two localities in the Wrangell Mountains prior to our inventory: Guerin Glacier (61° 36.82′ 141° 4.98′, *D. F. Murray 2103*, 4 August 1968 (ALA) (Murray 1971)) and Chitistone Pass (61°37′ N 141°58′ W, *D. F. Murray 865, 1218, 1343, 1541, 1817* (CAN)). The collections cited above from throughout the mountain ranges in the Park connect its distribution in the Alaska Range 107 km to the northwest (Mt. Hayes Quad: Rainbow Mountain, 63°20.0′ N 145°35.0′ W, *G. Smith 2604*, 7 July 1955 (ALA)) with stations 40 km to the east in the St. Elias Mountains, Yukon Territory (Cody 1996). This North America cordilleran species is rare in Alaska (GS S3) and in the Yukon Territory (Douglas et al. 1981). Map 129.

Draba stenoloba Ledeb., Alaska Whitlowgrass — CHUGACH MOUNTAINS: mesic forb tundra, upper Tebay Lake, 1219 m, 61°12.18′ N 144°23.8′ W, *M. Duffy 91114*, 12 August 1991; occasional in mesic meadow and heath tundra on SW-facing slope, plateau NW of Nerelna Creek, 1372 m, 61°26.66′ N 144°17.69′ W, *Roland & D'Auria 96-448B*, 10 July 1996; occasional in well-drained forb-graminoid meadow on S-facing hill, pass between Amy Creek and Klu River, 1164 m, 61°4.01′ N 143°34.83′ W, *C. Roland 96-526*, 13 July 1996; *Luetkea* meadow underlain by glacial outwash, Falls Creek, 1006 m, 61°16.84′ N 144°29.86′ W, *C. Roland 96-554*, 15 July 1996; steep SW-facing scree slope, Goat Creek, 1487 m, 60°59.5′ N 142°1′ W, *Batten & Barker 96-221C*, 28 July 1996; few in bare soil of E-facing cut bank, 12-mile Creek, Granite Range, 1326 m, 60°50.21′ N 142°30.85′ W, *C. Roland 96-785, 96-817*, 29 July 1996; occasional in moss and organic soil of herbaceous vegetation, plateau NW of Nerelna Creek, 1372 m, 61°26.66′ N 144°17.69′ W, *M. Cook 96303*, 7 July 1996; scattered in bare mineral soil and moss along sparsely vegetated ridge, ridge between Canyon, Pass and Tenas Creeks, 1682 m, 61°24.28′ N 144°21.61′ W, *Cook & Losso 96323*, 7 July 1996; scattered in forb herbaceous vegetation along stream, plateau between Tebay River, Hanagita River and Grant Creek, 1250 m, 61°17.65′ N 143°56.34′ W, *M. Cook 96368, 96411*, 7 July 1996; scattered on alpine forb herbaceous slope, vic. Hanagita Peak, 1186 m, 61°4.91′ N 143°38.86′ W, *M. Cook 96417, 96429*, 7 July 1996; SE-facing rock outcrops, Upper Golconda Creek, 1311 m, 61°2.8′ N 143°25.64′ W, *L.A. & E.G. Viereck 11071*, 7 July 1996. GULF OF ALASKA: ericaceous dwarf scrub alpine tundra, nunatak 3.5 km NW of Hanna Lake, 610 m, 60°9.95′ N 143°6.8′ W, *M. Duffy 9263*, 13 June 1992. NUTZOTIN MOUNTAINS: rare, with seral herbs on dry, S-facing bluff above Beaver Creek, 1097 m, 62°1′ N 141°11′ W, *Parker & Gracz 6832*, 10 August 1996; WRANGELL MOUNTAINS: occasional in protected gully draining blocky talus slope, Kuskulana Pass, 1545 m, 61°33.72′ N 143°39.7′ W, *C. Roland 96-716*, 26 July 1996.

This mustard, a North American cordilleran species, was known from one locality in the Wrangell Mountains (Bonanza Ridge, 61°30′ N 142°51′ W, *Nordell & Schmitt 62, 238, 483*, 2 July 1976 (LD & ALA) (Nordell and Schmitt 1978)) and from Yakutat Bay (*F. Funston 96*, 1892 (US) (Coville and Funston 1896; Hultén 1941)). The specimens cited above extend its range up to 230 km from the previous collections. The closest stations to our collections are 43 km to the east (Cordova Quad 60°58.0′ N 145°00.0′ W, *C.L. Parker 1778*, 12 August 1986 (ALA)) and 207 km to the north in the Alaska Range (Gulkana Quad: 62°57.0′ N 145°31.0′ W, *D. Mesiar DCM-48*, 3 July 1979 (ALA)). Map 130.

Draba stenopetala Trautv., Anadyr Whitlowgrass — CHUGACH MOUNTAINS: occasional on talus slope and

Dryas tundra, Hundell Creek, 1585 m, 61°36.75′ N 144°42.2′ W, *M. Cook 93466*, 28 August 1993; rocky tundra knoll on ridge crest, vic. East Fork Kiagna River, Granite Range, 1487 m, 60°59.5′ N 142°1′ W, *Batten & Barker 96-278*, 29 July 1996; occasional in gravel patches, Nerelna Creek plateau, 1372 m, 61°26.66′ N 144°17.69′ W, *M. Cook 96307*, 8 July 1996. MENTASTA MOUNTAINS: scattered in red gravel scree, SE-facing slope above Totschunda Creek, 1494 m, 62°28.28′ N 142°40.5′ W, *Cook & Shea 96286*, 3 July 1996; common in gravel on orange-colored rubble slope, Caribou Creek, 1158 m, 62°35.7′ N 143°27.87′ W, *Roland & D'Auria 97-017*, 26 June 1997. NUTZOTIN MOUNTAINS: NW-facing steep, exposed talus slope, Gold Hill, 1585 m, 62°6.73′ N 141°51.82′ W, *M. Cook 9270*, 27 June 1992; *Dryas* tundra ridge between Fogenbera Pass & Shotgold Creek, 1783 m, 61°53.28′ N 141°37.1′ W, *M. Cook 92457*, 8 July 1992; occasional on S-facing slope in *Dryas-Rhacomitrium* tundra, volcanic plateau between Bryan and Willow Creeks, 1829 m, 61°58.97′ N 141°50.03′ W, *M. Cook 95058*, 18 June 1995; alpine fellfield, on ridgetop east of Mt. Drum, 1768 m, 62°4.5′ N 144°22.8′ W, *K.A. Teare 1683*, 4 July 1984. WRANGELL MOUNTAINS: alpine tundra, slope above Nabesna Glacier moraine, 1768 m, 61°56.6′ N 143° W, *M. Duffy 92113*, *M. Cook 9262*, 26 June 1992; *Dryas*-sedge tundra, NW slope Mt. Sanford, 1295 m, 62°21.17′ N 144°24.52′ W, *M. Cook 93109*, 9 June 1993; rare on E-facing gravel slope, northeast slope of Mt. Drum, 1433 m, 62°8.83′ N 144°30.18′ W, *Cook & Roland 94054A*, 11 June 1994; scattered on stony alluvium of cinder cone, N slope Mt. Sanford, 1722 m, 62°23.4′ N 144°15.9′ W, *C. Roland 94-004*, 6 June 1994; scattered on steep S-facing rubble, W slope Mt. Sanford, 1615 m, 62°13.59′ N 144°26.06′ W, *C. Roland 94-042*, 9 June 1994; rare in gravel of dry *Salix*-lichen tundra, Cooper Pass, 1942 m, 62°17.16′ N 142°31.44′ W, *C. Roland 94-290*, 24 July 1994; scattered clumps on basalt tuff, Cone Ridge, 2073 m, 62°8.21′ N 143°18.47′ W, *M. Cook 94393*, 26 July 1994; rare in bare mineral soil, Chetaslina plateau, 1615 m, 61°56.51′ N 144°25.93′ W, *M. Cook 94467A*, 15 August 1994; occasional in bare mineral soil of volcanic avalanche deposits, Nadina Glacier, 1768 m, 62°2.85′ N 144°41′ W, *M. Cook 94413*, 30 August 1994; rare in gravel on moderate S-facing slope in sandy sites, Jaegar Mesa, 1893 m, 62°15.9′ N 143°1.24′ W, *C. Roland 95-118*, 1 July 1995; patchy on unstable gravel and cobble scree slope, Crystalline Hills, 1585 m, 61°23.59′ N 143°31.85′ W, *M. Cook 95274*, *C. Roland 95-234*, 18 July 1995; occasional in gravel frost scars, Black Mountain, 1481 m, 62°20.85′ N 143°44.9′ W, *Cook & Beck 95147*, 7 July 1995; scattered in moist, barren limestone gravel on gentle, NW-facing slope, 1868 m, 61°37.85′ N 144°1.01′ W, *C. Roland 96-585A*, 16 July 1996; occasional in limestone gravel, ridge between headwaters of Pass and East Fork of Copper Creeks, 1792 m, 61°39.82′ N 144°0.18′ W, *C. Roland 96-591*, 16 July 1996; occasional in morainal deposits, valley between Ruddy Mountain and Mt. Drum, 1615 m, 62°4.61′ N 144°46.39′ W, *C. Roland 96-325*, 2 July 1996; few in limestone gravel talus, Kuskulana Pass, 1545 m, 61°33.72′ N 143°39.7′ W, *M. Cook 96550*, 26 July 1996; rare in loose gravel on barren SW-facing slope of Snyder Peak, 1524 m, 62°4.47′ N 144°30.51′ W, *C. Roland 96-382*, 5 July 1996.

This amphiberingean arctic-alpine species, unknown previously from the Park, is now known from 25 localities in the Western and Northern Wrangells, Mentasta and Nutzotin Mountains. Our collections connect its distribution in the Alaska Range 147 km to the northwest (Hultén 1968) with the distribution in the Yukon Territory 105 km to the east (Cody 1996). The number of localities in the Western Wrangell Mountains may indicate that there was a local refugium from which these populations are derived. Hamilton and Thorson (1983) have suggested that the mountain slopes adjacent to Lake Ahtna in the Copper River basin could have been ice free at the end of the Wisconsin glaciation. Likewise, the populations in the Mentasta and Nutzotin Mountains, being close to the ice-free corridor, may represent areas that were ice-free earlier. This mustard is considered rare in Alaska (G3 S3S4) and in the Yukon Territory (Douglas et al. 1981). Map 131.

Erysimum pallasii (Pursh) Fern., Pallas' Wallflower — MENTASTA MOUNTAINS: bare mineral soil on S-facing limestone scree slope, Soda Lake, 1173 m, 62°32.36′ N 142°53.98′ W, *M. Cook 94322*, 22 July 1994; occasional in steep, loose, bare rubble on S-facing slope, Devils's Mountain, 1530 m, 62°25.62′ N 142°53.93′ W, *C. Roland 96-348*, 3 July 1996; few in unstable reddish gravel scree, Devils's Mountain, 1530 m, 62°25.62′ N 142°53.93′ W, *M. Cook 96279*, 7 July 1996. NUTZOTIN MOUNTAINS: scattered on SW-facing rubble slope, Carl Creek, 1920 m, 62°3.52′ N 141°36.27′ W, *C. Roland 94-084*, 20 June 1994; rare on very unstable S-facing gravel size scree slope, Horsfeld Creek, 1768 m, 62°2.88′ N 141°13.18′ W, *M. Cook 94150*, 24 June 1994; scattered within orange hypabyssal rhyolite unit on ridge, volcanic plateau between Bryan and Willow Creeks, 1829 m, 61°58.97′ N 141°50.03′ W, *M. Cook 95049*, 18 June 1995; few in dry basalt gravel and sand, Wiki Creek, 1411 m, 61°54.46 N 141°10.68′ W, *M. Cook 96089*, *C. Roland 96-066*, 10 June 1996; scattered in scree just below ridge, pass between Cabin and Wiki Creeks, 1615 m, 61°53.7′ N 141°11.64′ W, *M. Cook 3173*, 14 June 1998 (ALA); scattered in unstable scree and amongst rock outcrops, Wiki Basin, 1524 m, 61°54.77′ N 141°11.05′ W, *M. Cook 3188*, 15 July 1998 (ALA). WRANGELL MOUNTAINS: rare unstable, limestone scree, Lime Creek, 1646 m, 61°46.25′ N 141°50.36′ W, *M. Cook 94115*, 21 June 1994.

129. Draba ruaxes

130. Draba stenoloba

131. Draba stenopetala

132. Erysimum pallasii

This circumpolar arctic-alpine species was known from two localities in the Wrangell Mountains: Russell Glacier (61°42.05′ 141°44.75′ *D. F. Murray 2156*, 10 August 1968 (ALA)) and Skolai River (61°37′ N 142°3′ W, *R. Scott s.n.*, 1976 (MICH) (Scott 1968)). The collections cited above extend its range 112 km to the east into the Mentasta Mountains and connect the distribution in the Alaska Range 286 km to the northwest (Healy Quad: Polychrome Pass, 63°31.0′ N 149°56.0′ W, *A. & R.A. Nelson 3818*, 14 July 1939 (ALA)) with the range 57 km to the east in the Yukon Territory (Cody 1996). This species is considered rare in Alaska (G4 S3). Map 132.

Eutrema edwardsii R. Br., Edwards' Mock Wallflower — NUTZOTIN MOUNTAINS: *Dryas* tundra, ridge between Fogenbera Pass and Shotgold Creek, 1783 m, 61°53.28′ N 141°37.1′ W, *M. Cook 92448*, 8 July 1992; scattered in wet moss of graminoid swale, volcanic plateau between Bryan and Willow Creeks, 1829 m, 61°58.97′ N 141°50.03′ W, *M. Cook 95042*, 17 June 1995; scattered in mesic graminoid herbaceous/shrub birch-willow scrub, Wiki Creek, 1411 m, 61°54.46′ N 141°10.68′ W, *M. Cook 96065*, 9 June 1996. ST. ELIAS MOUNTAINS: rare in late snow melt area on N-facing slope, wet silt with sparse forbs, Mt. Chitina, 2073 m, 60°57.74′ N 141°17.33′ W, *M. Cook 95250*, 16 July 1995. WRANGELL MOUNTAINS: in standing water, isolated ridge SW of Long Glacier, 1372 m, 61°45.83′ N 144°12.12′ W, *K.A. Teare 84-86*, 18 July 1984; alpine tundra, 152 m above and E of Nabesna Glacier moraine, 1768 m, 61°56.6′ N 143° W, *M. Cook 92556*, 26 June 1992; *Dryas*-sedge tundra, NW slope of Mt. Sanford, between Sanford and Boulder Creeks, 395 m, 62°21.17′ N 144°24.52′ W, *M. Cook 93124*, 9 June 1993; seep area in talus on rock outcrop, Jaegar Mesa, 1893 m, 62°15.9′ N 143°1.24′ W, *Moran & Roland 95-31*, 30 June 1995; patchy in moss next to rivulet with dwarf willows and alpine forbs, Crystalline Hills, 1585 m, 61°23.59′ N 143°31.85′ W, *M. Cook 95279*, 18 July 1995; polygon tundra, Lakes Plateau, 1890 m, 62°4.4′ N 143°23.5′ W, *Potkin & Leggett 95-069C*, 29 July 1995; moist meadow intermixed with clumps of *Salix lanata,* Nikolai Pass, 1280 m, 61°26′ N 142°40′ W, *Batten & Barker 96-183B*, 26 July 1996 (ALA).

This circumpolar arctic-alpine species was previously known from two localities in the Wrangell Mountains: Russell Glacier (61° 41.88′ N 141° 44.49′ W, *D. F. Murray 2203*, 11 August 1968 (ALA)) and Chitistone Pass/upper Skolai River Valley, 61°37′ N 142°3′ W, *R. Scott s.n.*, 1967 (MICH) (Scott 1968) and *D. F. Murray 1035*, 21 July 1967 (CAN)). The new collections cited above extend its range 148 km west into the Wrangells and 87 km south into the St. Elias Mountains and connect the distribution in the Alaska Range 180 km to the northwest (Healy Quad: Cantwell, 63°24.0′ N 148°56.0′ W, *L.J. Palmer 1931*, 10 July 1927 (ALA)) with the distribution 137 km to the east in the Yukon Territory (Cody 1996). Map 133.

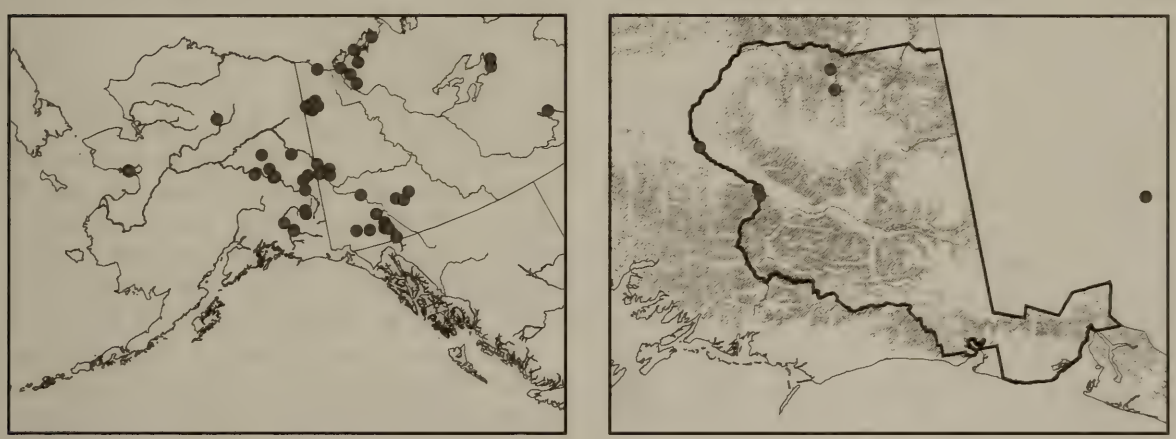
Halimolobos mollis (Hook.) Rollins, Soft Fissurewort — CHUGACH MOUNTAINS: Third Lake, 4.8 km N of Chitina, 396 m, 61°34.12′ N 144°26.37′ W, *M. Cook 8962*, 4 June 1989. MENTASTA MOUNTAINS: occasional in disturbed sites on dry, S-facing slopes in sagebrush-grass vegetation, SW end of Devil's Mt., 942 m, 62°24.95′ N 142°54.86′ W, *C. Roland 96-233, M. Cook 96240*, 22 June 1996. WRANGELL MOUNTAINS: common in dry, rocky areas on steep SE-facing slope in sagebrush-grass vegetation, Nabesna River, 0.6 km S of Bond Creek, 1106 m, 62°15.05′ N 142°54.68′ W, *C. Roland 96-165, M. Cook 96188*, 19 June 1996.

This North America arctic-alpine mustard was collected in the vicinity of the Park at Copper Center (*W.L. Poto 14*, 1 June 1902 (US) (Poto 1902*; Hultén 1941-1950); *C.W. Heidemann 31*, 1908 (US) (Hultén 1941-1950)) and at Chitina (*J.P. Anderson 2017*, 1935 (S) (Hultén 1941-1950)). The new collections cited above along the Nabesna River are 130 km north of the Copper Center station and 112 km south of a station near the Robertson River (*O.J. & M.E. Murie, 1921* (US) (Hultén 1941-1950)). Map 134.

Lesquerella arctica (Wormsk.) S. Wats., Arctic Bladderpod — CHUGACH MOUNTAINS: SE-facing bluff above road and W of bridge, confluence of Chitina and Copper Rivers, 274 m, 61°31.55′ N 144°24.85′ W, *M. Cook 93102*, 21 May 1993; SW-facing scree, Goat Creek, 1487 m, 60°59.5′ N 142°1′ W, *Batten & Barker 96-297*, 31 July 1996. MENTASTA MOUNTAINS: few localized on S-facing limestone talus slope sparsely vegetated with midgrass-herbs, Soda Lake, 1173 m, 62°32.36′ N 142°53.98′ W, *M. Cook 94323*, 22 July 1994; river terrace, Totschunda Creek, 725 m, 62°26.94′ N 142°40.8′ W, *C. Roland 96-250*, 23 June 1996. ST. ELIAS MOUNTAINS: dry benchland meadow, Chitina River, 335 m, 61°9.02′ N 142°39.95′ W, *D. Miquelle 84-10*, 20 June 1984; few localized at edge of active flood zone on sand spit 0.8 km N of Jakes Bar, Chitina River, 93 m, *M. Cook 94230*, 9 July 1994 (ALA); few localized in dry sandy clay mineral soil on ridge between Logan and Walsh Glaciers, 1951 m, 60°53.94′ N 141°6.75′ W, *M. Cook 95221*, 13 July 1995. WRANGELL MOUNTAINS: scattered on limestone outcrop above mixed *Picea glauca*-Poplar forest, Crystalline Hills, 618 m, 61°23.1′ N 143°36.01′ W, *M. Cook 3146*, 24 June 1998.

This circumpolar arctic-alpine bladderpod was collected at Chitina (61°31.55′N 144° 27.89′W, *L. Spetzman 2557* (CAN) (Rollins 1973); *D.F. Murray 6161, 6232* (ALA)) and on the upper Chitina River (61°01.84N′ 141°37.27′W, *H.M. Laing 91, 92* (CAN) (Porsild 1939, Hultén 1941-1950)). When A.E. Porsild classified Laing's collection, he determined these specimens to be *L. arctica* var. *purshii* Wats. (Porsild 1939). However, Hultén (1945), Rollins (1973) and Cody (1996) do not recognize this variety. This plant has a restricted distribution in the Park but with a wide ecological tolerance. It is now known from eight localities along the Chitina River and in the Mentasta Mountains on floodplains, alpine scree and dry south-facing bluffs. The collections cited above extend its range 183 km to the north into

133. Eutrema edwardsii



134. Halimolobos mollis

135. Lesquerella arctica

136. Smelowskia borealis

the Mentasta Mountains. These collections also connect the distribution between the Alaska Range 243 km to the northwest (Rapids, 63°37.56′N 145°53.06′W, *O.J. Murie s.n.*, 7 June 1992 (US), *E. Scamman 216* (G, S) (Hultén 1941-1950)) with the distribution 188 km to the east in the Yukon Territory (Cody 1996). Map 135.

Smelowskia borealis (E. L. Greene) Drury & Rollins, Northern Smelowskia — MENTASTA MOUNTAINS: few on sparsely vegetated scree slope, Totschunda Creek, 1494 m, 62°28.28′ N 142°40.5′ W, *M. Cook 96296*, 7 July 1996; few in unstable limestone scree, Lost Creek, 1646 m, 62°34.58′ N 143°5.58′ W, *C. Roland 94-265*, 23 July 1994; locally abundant in limestone gravel, Trail Creek, 1615 m, 62°36.05′ N 143°17.63′ W, *C. Roland 95-012*, 6 June 1995. NUTZOTIN MOUNTAINS: rare on S-facing granidorite boulder-cobble slope, Carl Creek, 1859 m, 62°3.07′ N 141°35.01′ W, *M. Cook 94129*, 22 June 1994; scattered on steep, unstable S facing fine scree slope, Horsfeld Creek, 1768 m, 62°2.88′ N 141°13.18′ W, *M. Cook 94159*, 24 June 1994. WRANGELL MOUNTAINS: N-facing scree slope, Lime Peak, 1707 m, 61°28.41′ N 141°29.44′ W, *M. Duffy 92144*, 7 July 1992; occasional in loose limestone and greenstone rubble, Alice Peak, 1628 m, 61°39.82′ N 144°7.76′ W, *C. Roland 96-396A*, 5 July 1996; occasional in gravel 15 m below ridge, Elliot Creek, 1926 m, 61°38.99′ N 144°3.51′ W, *M. Cook 96470*, 7 July 1996; steep unstable scree of loose shaley orange-tan rocks, Nikolai Pass, 1280 m, 61°26′ N 142°40′ W, *Batten & Barker 96-024*, 23 July 1996.

This species is an Alaska-Yukon endemic with an arctic-alpine distribution. Hultén (1942) indicated that it was a remnant of a tertiary type that survived only in unglaciated areas. It was known from four localities in the Wrangell-St. Elias Mountains: Russell Glacier (61°42.0′ N 141°45.0′ W, *D. F. Murray 2180*, 11 August 1968 (ALA)); Guerin Glacier (61°37.0′ N 141°05.0′ W, *D. F. Murray 2096*, 4 August 1968 (ALA)); Sheep Glacier (61°42.0′ N 141°39.0′ W, *D. F. Murray 2254*, 15 August 1968 (ALA)) and Chitistone Pass/upper Skolai River Valley (61°37′ N 142°3′ W, 604 m, *R. Scott 2238*, 1967 (MICH) (Scott 1968)). A collection in Hultén (1968) on the upper Copper River is that of W.L. Poto from the East Fork of the Chistochina (62°53.78′N 144°40.20′W, *#157*, 22 August 1902 (US) (Poto 1902*)). The Chistochina River was mapped incorrectly in Hultén (1941) and we were not able to locate an annotation for the station that appears on the upper Copper River in Hultén (1968). The collections cited above extend the range of this species 124 km north into the Mentata Mountains, 111 km west into the western Wrangell Mountains and connect the distribution 88 km to the northwest in the Alaska Range (Mt. Hayes Quad: Rainbow Mountain, 63° 13′ N, 145° 38′ W, 63°15.0′ N 145°35.0′ W, *C.L. Parker 1734*, 2 September 1985 (ALA)) with the range to the east in the Yukon Territory (Cody 1996). Map 136.

Smelowskia calycina (Stephan) C.A. Meyer s.l., False Candytuft — NUTZOTIN MOUNTAINS: S-facing scree slope, knob 2.4 km W of Ptarmigan Creek, 1494 m, 61°55.55′ N 141°6.72′ W, *M. Cook 92467*, *M. Duffy 92185*, 9 July 1992; few in loose rhyolite gravels at edge of *Dryas*/graminoid tundra stringers on W-facing slope, Wiki Creek, 1433 m, 61°53.9′ N 141°9.51′ W, *C. Roland 94-109*, 22 June 1994; sparsely vegetated SW-facing scree slope, Horsfeld Creek, 1768 m, 62°2.88′ N 141°13.18′ W, *M. Cook 94156*, *C. Roland 94-130*, 24 June 1994 (ALA); scattered on rhyolite talus, plateau between Bryan and Willow Creeks, 1829 m, 61°58.97′ N 141°50.03′ W, *M. Cook 95043*, 17 June 1995; very rare in gravels on dry tundra knob, Wiki Creek, 1411 m, 61°54.46′ N 141°10.68′ W, *C. Roland 96-059, 96-076*, 8 June 1996; few scattered in scree, Wiki Basin, 1524 m, 61°54.77′ N 141°11.05′ W, *M. Cook 3185*, 15 July 1998 (ALA); scattered in scree, Sonja Creek, 1494 m, 61°57.14′ N 141°21.43′ W, *M. Cook 3193*, 16 July 1998 (ALA). WRANGELL MOUNTAINS: N-facing scree slope, Lime Creek, 1707 m, 61°47.2′ N 141°49.06′ W, *M. Cook 92509, 92512*, *M. Duffy 92145*, 7 July 1992; *Dryas* sedge tundra, NW slope of Mt. Sanford between Sanford and Boulder Creeks, 395 m, 62°21.17′ N 144°24.52′ W, *M. Cook 93121*, 9 June 1993; rare in rocks on moderate S-facing slope, Jaegar Mesa, 1893 m, 62°15.9′ N 143°1.24′ W, *C. Roland 95-117A*, 1 July 1995.

This species was collected in the vicinity of Russell Glacier (61°41.64′N 141°44.85′W, *D.F. Murray 2200*, 11 August 1968 (ALA) (Murray 1971)). The new collections cited above extend its range 156 km to the east into the western Wrangell Mountains. The closest stations to those in the Wrangell and Nutzotin Mountains are 405 km to the west in the McGrath Quad (Farewell Mountain, 62°31.0′ N 153°43.0′ W, *C. Parker 900*, 11 July 1983 (ALA)), 439 km to the northwest in the Tanana Quad (Moose Creek, 65°36.0′ N 150°41.0′ W, *K.C. Kassler 282*, 25 June 1979 (ALA)) and 323 km to the northeast in the Yukon Territory (Cody 1996).

Five of the specimens cited above were determined as *S. calycina* (Stephan) C.A. Meyer var. *porsildii* Drury & Rollins based on the presence of all entire, linear leaves. However these individuals came from populations that also had plants with either all divided leaves or both types of leaves. In our area, leaf shape appears to be a plastic character, whereas populations in unglaciated Alaska, easternmost Siberia and Western North America are more consistent with regards to the simple leaf shape (Hultén 1944). Hultén commented that, "This species is a fine example of the geographical conditions in species older than the Pleistocene glaciation" and suggested that the simple-leaved form (*S. calycina* var. *porsildii*) survived glaciation whereas the divided leaf form is a derived state. The occurrence of both forms in the Nutzotin and Wrangell Mountains, populations that are 800 km disjunct from the main arctic range, may indicate that these areas were ice-free earlier. Map 137.

Subularia aquatica L., Awlwort — WRANGELL MOUNTAINS: common along muddy shoreline, Fox Farm Lake, 727 m, 62°19.98′ N 144°50.02′ W, *M. Cook 95311, 95303*, *C. Roland 95-252*, 25 July 1995; gravel bottom, Chelle Lake, 930 m, 62°11.56′N, 144°51.97′W, *M. Cook 3606*, 1 September 2000.

This circumpolar boreal-montane aquatic mustard is of restricted distribution in Alaska and rare in the Yukon Territory (Douglas et al. 1981). The stations in the Wrangell Mountains cited above are 127 km south of the closest station in the Alaska Range near Summit Lake (*A.E. & R.T. Porsild 546*, July 1926 (CAN) (Hultén 1941-1950)). Map 138.

Thlaspi arcticum Pors., Arctic Pennycress — WRANGELL MOUNTAINS: NE-facing scree slopes, Iron Mountain, 1676 m, 61°37.64′ N 144°1.42′ W, *M. Duffy 91150*, 27 August 1991, *C. Roland 96-590*, *M. Cook 96465*, 16 July 1996.

This Alaska-Yukon endemic with an arctic-alpine distribution is one of the rarest plants in the Park, known only from the one locality cited above. It is rare in Alaska (G3 S3) and in the Yukon Territory (Douglas et al. 1981). Most localities are widely disjunct in Alaska and the Yukon and represented by very few individuals (Murray and Lipkin 1987). The collection in the southwest Wrangells cited above is 252 km northeast of a station in the Anchorage Quad (North Campbell Creek Canyon, 61°07.17′ N 149°29.75′ W, *Lichvar et al. 8085*, 19 July 1994 (ALA)), 318 km southeast of a station in the Healy Quad (Windy Creek, 63°24.0′ N 149°17.0′ W, *D. Heebner 100.2*, 7 July 1977 (ALA)) and 303 km west of a station in the Yukon Territory (Cody 1996). Map 139.

SAXIFRAGACEAE

Mitella pentandra Hook., Alpine Mitrewort — GULF OF ALASKA BASIN: tall forb herbaceous alpine tundra, Robinson Mountains, 671 m, 60°5.64′ N 142°17.17′ W, *M. Cook 9233*, *M. Duffy 92214*, 12 June 1992. ST. ELIAS MOUNTAINS: mixed forb herbaceous meadow, Icy Bay, 427 m, 60°0.76′ N 141°27.1′ W, *K. Beck s.n.*, 12 August 1987; heather tundra, Floral Pass, 549 m, 59°57.91′ N 139°57.76′ W, *M. Cook 87-146*, 21 August 1987; snowflush streamlet, Samovar Hills, 2200 m, 60°4.15′ N 140°28.75′ W, *M. Cook 92522*, 18 July 1992. WRANGELL MOUNTAINS: tall forb-graminoid herbaceous meadow, Lakina Glacier, 1219 m, 61°33.64′ N 143°19.01′ W, *M. Cook 96531*, *C. Roland 96-704*, 24 July 1996.

This species is North American with a cordilleran distribution and is rare in the Yukon Territory (Douglas et al. 1981). The collections cited above extend its range 212 km northeast into the Wrangell Mountains and 348 km east into the southern St. Elias mountains and connect the range 166 km to the east in the Yukon Territory (Cody 1996). Map 140.

Saxifraga adscendens L. ssp. *oregonensis* (Raf.) Baciagalupi, Small Saxifrage — CHUGACH MOUNTAINS: occasional in serpentinized ultramafic unit on ridge S of Chakina River, 1768 m, 61°6.19′ N 142°55.03′ W, *M. Cook 94229*, 8 July 1994; rocky ridge crest and W-facing slide rock, West Fork Goat Creek, 1487 m, 60°59.5′ N 142°1′ W, *Batten & Barker 96-294*, 29 July 1996 (ALA); scattered on moist gravel slope, Nelson Mountain, 1558 m, 61°19.37′ N 143°48.83′ W, *M. Cook 96370*, 7 July 1996. ST. ELIAS MOUNTAINS: rare in solifluction lobes, limestone ridge between Dan & Copper Creeks, 1554 m, 61°21.56′ N 142°26.43′ W, *M. Cook 94293*, 14 July 1994. WRANGELL MOUNTAINS: scattered in dry, rocky limestone talus, Lakina Glacier, 1219 m, 61°33.64′ N 143°19.01′ W, *M. Cook 96537*, *C. Roland 96-705*, 25 July 1996; few in fine gravels, in greenstone unit, Iron Mountain, 1868 m, 61°37.85′ N 144°1.01′ W, *M. Cook 96467*, 7 July 1996; bare organic soil and moss, Grotto Creek, 1847 m, 61°30.56′ N 142°24.79′ W, *M. Cook 96510*, 7 July 1996; scattered in moss and organic soil of limestone outcrops, Lakina Glacier, 1219 m, 61°33.64′ N 143°19.01′ W, *M. Cook 96537*, 7 July 1996.

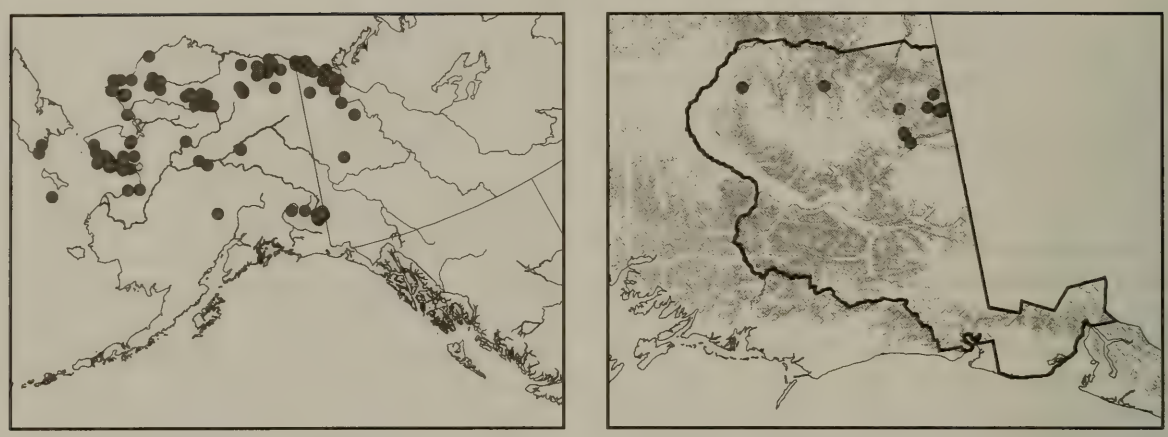
This North American cordilleran saxifrage was known from one locality in the Wrangell Mountains (Chitistone Pass, 61°37′ N 141°58′ W, 1979 m, *D. F. Murray 683, 1064* (CAN)). The collections cited above extend its range 107 km into the Western Wrangells and 103 km south into the Chugach Range. These collections join the cordilleran range 240 km to the southwest in the Anchorage Quad (Nike Site, 61°15.70′ N 149°32.25′ W, *Duffy et al. 381*, 29 June 1994 (ALA)) with the distribution 161 km to the east in the Yukon Territory (Cody 1996). Map 141.

Saxifraga bracteata D. Don (*S. sibirica* L.), Siberian Saxifrage — NUTZOTIN MOUNTAINS: occasional on rock-*Dryas-Rhacomitrium* SW-facing slope, Carl Creek, 1920 m, 62°3.52′ N 141°36.27′ W, *Cook & Roland 94091A*, 20 June 1994. ST. ELIAS MOUNTAINS: dry forb alpine herbaceous talus, Samovar Hills, 610 m, 60°8.35′ N 140°39.6′ W, *M. Cook 87-77*, 24 August 1987.

The specimens cited above extend the range of this amphiberingean saxifrage 259 km north into the Nutzotin Mountains and 180 km east to the Samovar Hills from Kayak Island (59°56.0′ N 144°23.0′ W, *Cunningham et al. 124-78*, 1 June 1978 (ALA)). These collections connect the Pacific Coastal range to the southwest with the range 348 km to the southeast (Hultén 1968). Map 142.

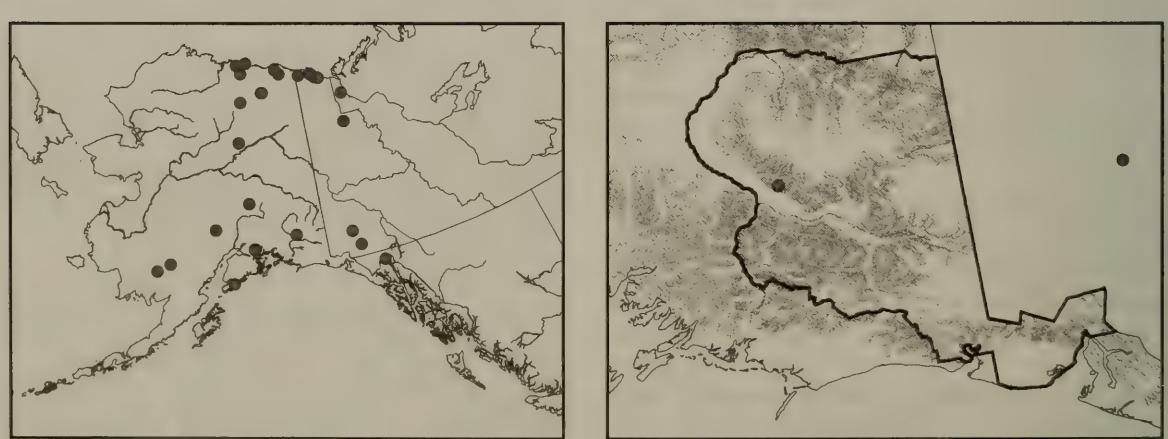
Saxifraga foliolosa R. Br., Leafystem Saxifrage — NUTZOTIN MOUNTAINS: occasional in volcanic ash, upper Flat Creek, 1323 m, 61°58.97′ N 141°41.25′ W, *C. Roland 95-045*, 17 June 1995. WRANGELL MOUNTAINS: sedge tundra frost boil, Cheshnina Plateau, 1640 m, 61°50.33′ N 144°22.5′ W, *M. Duffy 91087*, 21 July 1991; scattered in moist organic soil, Mesa Creek, 2073 m, 62°8.21′ N 143°18.47′ W, *M. Cook 94369*, *C. Roland 94-294*, 25 July 1994; bare moist mineral soil, Chetaslin Ridge, 1615 m, 61°56.51′ N 144°25.93′ W, *M. Cook 94483*, 16 August 1994; wet meadow, Jaegar Mesa, 1893 m, 62°15.9′ N 143°1.24′ W, *Moran & Roland 95-46*, 1 July 1995; Lakes Plateau, 1890 m, 62°4.4′ N 143°23.5′ W, *M. Potkin 95-148*, 30 July 1995.

This saxifrage is circumpolar with an arctic-alpine distribution. The stations cited above connect the range 110 km to the southwest at Thompson Pass (Valdez Quad, 61°08.0′ N 145°44.0′ W, *C.L. Parker 2362*, 21 July 1990 (ALA)) with the range 141 km to the north in the Alaska Range in the Mt. Hayes Quad (Upper Berry Creek, 63°30.0′ N 144°35.0′ W, *L.A. Spetzman 1038*, 5 August

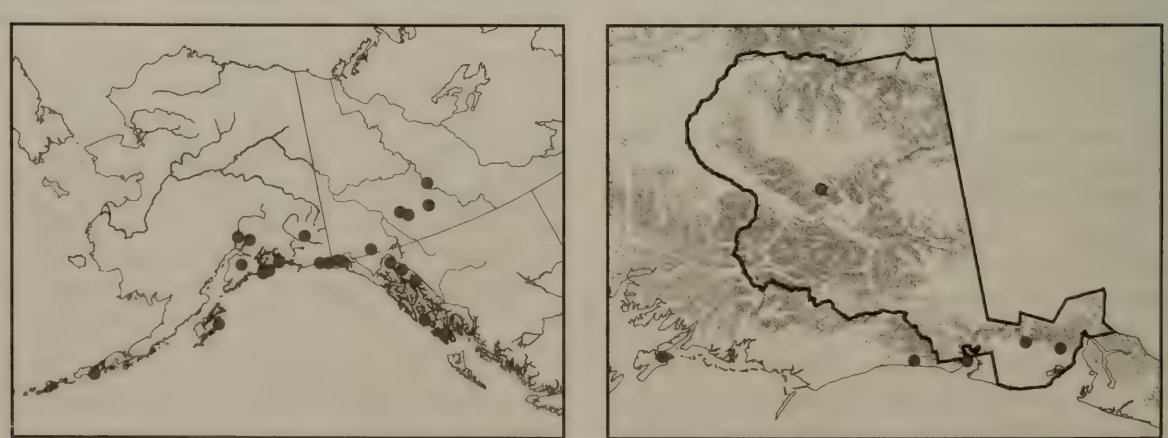


137. *Smelowskia calycina*

138. *Subularia aquatica*

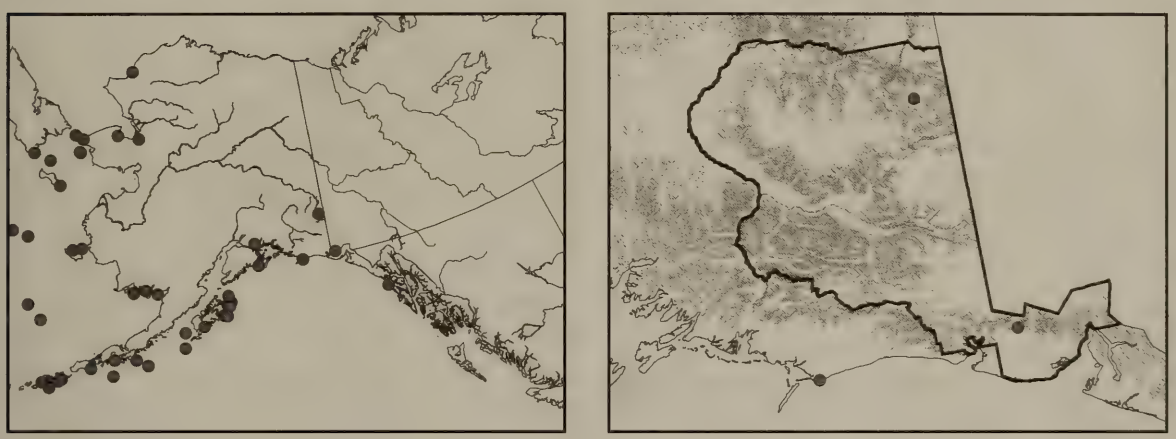


139. *Thlaspi arcticum*



140. *Mitella pentandra*

141. Saxifraga adscendens ssp. *oregonensis*



142. Saxifraga bracteata

143. Saxifraga foliolosa

144. Chamaerhodos erecta ssp. *nuttallii*

1957 (ALA)). It is considered rare in the Yukon Territory by Douglas et al. (1981). Map 143.

ROSACEAE

Chamaerhodos erecta (L.) Bunge ssp. *nuttallii* (Torr. & Gray) Hult., Little Rose — MENTASTA MOUNTAINS: locally abundant in bare soil on steep, S-facing slopes, Devil's Mountain, 942 m, 62°24.95′ N 142°54.86′ W, *C. Roland 96-225*, *M. Cook 96237*, 22 June 1996; occasional on gravel scree slope, NE slopes of Devils's Mountain, 1530 m, 62°25.62′ N 142°53.93′ W, *M. Cook 96284*, 3 July 1996.

This amphiberingian species is disjunct in the Mentasta Mountains from the Anchorage Quad, 242 km to the southwest (Mile 74 Glenn Highway, 61°46.0′ N 148°33.0′ W, *S.L. Welsh 5001*, 30 July 1965 (ALA)), the Eagle Bluff Quad 285 km to the north (64°50.0′ N 141°11.0′ W, *R. Lipkin 80-22*, 11 June 1980 (ALA)) and Kluane Lake in the Yukon Terriotry 194 km to the east. Two additional small populations of this amphiberigian species have been observed by M. Cook, one 7 km up the Nabesna River from the Devil's Mountain locality at the confluence with the Jacksina River (62°21.51′N 142°52.87′W) and one 8 km east and across the Nabesna River on a river terrace at Cabin Creek (62°23.57′N 142°46.74′W). Map 144.

Potentilla arguta Pursh ssp. *convallaria* (Rydb.) Keck, Tall Cinquefoil — CHUGACH MOUNTAINS: few on dry S-facing slope, Granite River, Granite Range, 884 m, 60°44.63′ N 142°6.05′ W, *M. Cook 96610*, 7 July 1996.

The specimen cited above is an extension of the range of this North American cinquefoil, 209 km to the east of a station near Thompson Pass (Hultén 1968), 244 km southeast of a station near Slana (Hultén 1968) and 207 km west of its distrubution in the Yukon Territory (Cody 1996). Map 145.

Potentilla biflora Willd., Two-Flower Cinquefoil — CHUGACH MOUNTAINS: rare in dwarf scrub tundra, Chakina River, 1768 m, 61°6.19′ N 142°55.03′ W, *M. Cook 94227*, 8 July 1994; locally common in *Dryas*-graminoid tundra, Verde Ridge, 1554 m, 61°14.03′ N 143°28.52′ W, *Roland & D'Auria 96-483*, 11 July 1996; occasional in *Dryas*-lichen tundra, Nerelna Creek plateau, 1372 m, 61°26.66′ N 144°17.69′ W, *M. Cook 96306*, 7 July 1996; occasional in *Dryas*-lichen tundra, Nelson Mountain, 1558 m, 61°19.37′ N 143°48.83′ W, *M. Cook 96375*, 7 July 1996. MENTASTA MOUNTAINS: *Dryas* forb tundra, limestone ridge between Lost and Platinum Creeks, 1646 m, 62°34.58′ N 143°5.58′ W, *M. Cook 94339*, 23 July 1994; upper Trail Creek, 1341 m, 62°37.09′ N 143°16.06′ W, *M. Potkin 95-042*, 26 July 1995; scattered in *Dryas*-lichen-moss stringers, Lost Creek, 1722 m, 62°36.45′ N 143°12.03′ W, *M. Cook 95179*, 5 July 1995; locally abundant in argillite scree, Totschunda Creek, 1561 m, 62°30.62′ N 142°47.21′ W, *C. Roland 96-365*, 4 July 1996. NUTZOTIN MOUNTAINS: alpine tundra, Sheep Creek, 1554 m, 62°8.61′ N 141°46.93′ W, *J. Bolivar 84-61*, 26 June 1984; dwarf scrub sedge tundra, Solo Mt., 1620 m, 62°11′ N 143°31.42′ W, *M. Cook 92052*, 8 July 1992; scattered in SE-facing limestone, Baultoff Creek, 1707 m, 62°9.13′ N 141°14.51′ W, *Cook & Roland 94191*, 28 June 1994; scattered in bare mineral soil, Cooper Pass, 1942 m, 62°17.16′ N 142°31.44′ W, *M. Cook 94342*, 24 July 1994. ST. ELIAS MOUNTAINS: common on N & S facing slopes in *Dryas* tundra & on ledges and crevices of limestone, ridge between Dan & Copper Creeks, 1554 m, 61°21.56′ N 142°26.43′ W, *M. Cook 94285*, 13 July 1994; occasional in *Dryas*-sedge-lichen tundra, Mt. Chitina, 2073 m, 60°57.74′ N 141°17.33′ W, *M. Cook 95256*, 16 July 1995. WRANGELL MOUNTAINS: moist silt and humus, ridge SW of Long Glacier, 1372 m, 61°45.83′ N 144°12.12′ W, *K.A. Teare 84-77B*, 18 July 1984; N-facing scree slope, Lime Peak, 1707 m, 61°28.41′ N 141°29.44′ W, *M. Duffy 92208*, 11 July 1992; *Dryas*-sedge tundra, Iron Mountain, 1676 m, 61°22.15′ N 144°1.4′ W, *M. Cook 92516*, 11 July 1992; *Dryas*-sedge tundra, NW slope of Mt. Sanford between Sanford and Boulder Creeks, 395 m, 62°21.17′ N 144°24.52′ W, *M. Cook 93117*, 9 June 1993; W-facing slope, volcanic ridge between upper Jacksina River and Mesa Creek, 2073 m, 62°8.21′ N 143°18.47′ W, *C. Roland 94-318A*, 27 July 1994; tundra, Jaegar Mesa , 1893 m, 62°15.9′ N 143°1.24′ W, *Moran & Roland 95-57*, 3 July 1995; dry tundra near ridge crest, Nikolai Pass, 1280 m, 61°26′ N 142°40′ W, *Batten & Barker 96-046*, 23 July 1996; occasional in gravel on limestone ridge, Alice Peak, 1628 m, 61°39.82′ N 144°7.76′ W, *C. Roland 96-389*, 5 July 1996; few at edge of *Dryas*-graminoid heath adjacent to limestone cliff, headwaters of Grotto Creek, 1847 m, 61°30.56′ N 142°24.79′ W, *M. Cook 96511*, 7 July 1996; scattered in limestone gravel talus, Kuskulana Pass, 1545 m, 61°33.72′ N 143°39.7′ W, *M. Cook 96551*, 7 July 1996.

This amphiberingian arctic-alpine species was previously known from only two localities in the Wrangell Mountains: between the Sanford River and Slana on the Copper River trail (62°24.70 144°5.68, 1372 m, *W.L. Poto s.n.*, 30 July 1902 (US) (Poto 1902*; Hultén 1941–1950)) and Frederika Glacier (61°41.95 142°12.59, 1128 m, *R. Scott 2651*, 7 July 1968 (ALA) (Scott 1968)). It is now known throughout the mountains of the Park. The specimens cited above extend its range 114 km south into the Chugach Mountains and 72 km north into the Nutzotin Mountains. Map 146.

Potentilla diversifolia Lehm., Varileaf Cinquefoil — CHUGACH MOUNTAINS: mixed forb meadow, Flood Creek, 61°42.88′ N 141°58.65′ W, *M. Duffy 91061*, 16 July 1991; subalpine meadow, Towhead Mountain, 1433 m, 61°3.21′ N 142°39.8′ W, *Duffy & Barnes 96-164, 96-174*, 7 August 1996; willow thickets, Granite River, 823 m, 60°44′ N 142°13′ W, *Batten & Barker 96-362*, 30 July 1996; occasional in mixed herbaceous meadow, Nerelna Creek Plateau, 1372 m, 61°26.66′ N 144°17.69′ W, *M. Cook 96301, 96409*, 7 July 1996; forb herbaceous

145. Potentilla arguta ssp. *convallaria*

146. Potentilla biflora

147. Potentilla diversifolia

148. Potentilla drummondii

meadow, Lake Creek, 975 m, 61°11.4′ N 143°49.45′ W, *M. Cook 96403*, 7 July 1996; mixed forb meadow, Hanagita Peak, 1186 m, 61°4.91′ N 143°38.86′ W, *M. Cook 96420*, 7 July 1996; forb meadow, W. Fork Goat Creek, 1487 m, 60°59.8′ N 142°11.8′ W, *M. Cook 96585*, 28 July 1996; Upper Golconda Creek, 1311 m, 61°2.8′ N 143°25.64′ W, *L. A. & E. G. Viereck 11069*, 7 July 1996; occasional in ericaceous dwarf scrub tundra, Juniper Island, 1346 m, 60°36.17′ N 142°14.96′ W, *M. Cook 94233*, 10 July 1994; Goat Creek, 1487 m, 60°59.5′ N 142°1′ W, *Batten & Barker 96-273*, 29 July 1996. St. Elias Mountains: meadows and tundra, Lime Butte, 1554 m, 61°21.56′ N 142°26.43′ W, *C. Roland 94-238A*, 13 July 1994. Wrangell Mountains: mesic graminoid-forb meadow, Chetaslina Ridge, 1615 m, 61°56.51′ N 144°25.93′ W, *M. Cook 94486*, *C. Roland 94-344A*, 17 August 1994; ridge SW of Long Glacier, 1372 m, 61°45.83′ N 144°12.12′ W, *C. Teare 84-76B*, 18 July 1984; steep E-facing meadow, Nikolai Mine, 1695 m, 61°27′ N 142°39′ W, *Batten & Barker 96-077*, 24 July 1996; graminoid meadow, Boulder Lake, 1036 m, 62°31.27′ N 144°11.26′ W, *M. Cook 95361*, 2 August 1995.

This species is North American with a cordilleran distribution. The collections cited above connect the range 70 km to the west on the Richardson Highway (Hultén 1968) with the range 141 km to the southeast in the Yukon Territory. Map 147.

Potentilla drummondii Lehm., Drummond's Cinquefoil — Chugach Mountains: mesic forb tundra, Upper Tebay Lake, 1219 m, 61°12.18′ N 144°23.8′ W, *M. Duffy 91109*, 12 August 1991; occasional in dry graminoid meadow, Granite River, Granite Range, 884 m, 60°44.63′ N 142°6.05′ W, *M. Cook 96607*, 7 July 1996; scattered in ericaceous-graminoid meadow, vic. 12-mile Creek, Granite Range, 1271 m, 60°48.85′ N 142°33.52′ W, *M. Cook 96632*, 7 July 1996; scattered between willow, Upper Falls Creek, 655 m, 61°14.17′ N 144°28.24′ W, *L. A. & E.G. Viereck 11038*, 7 July 1996; mixed mesic forb herbaceous snow beds, Middle Fork of the Bremner River, 869 m, 60°55.05′ N 143°43.86′ W, *Duffy & Barnes 96-083*, 6 August 1996; few at margin of bluejoint herb meadow, Upper Tebay Lake, 579 m, 61°11′ N 144°24′ W, *Parker & Gracz 6739*, 8 August 1996. St. Elias Mountains: moist herbaceous patches among birch shrubs, upper Chitina River, 503 m, 61°5.35′ N 141°56.3′ W, *Parker & Duffy 6704*, 6 August 1996.

This North American cordilleran species is disjunct in Alaska from southern British Columbia, southwest Alberta, the Cascade Mountains of Oregon, Washington and Northern California (Hitchcock and Cronquist 1961). There are only two other known localities of this species in Alaska which are 240 km to the west of the specimens cited above from the Chugach Mountains (Seward Quad: Turnagain Pass, 60°48.0′ N 149°11.0′ W, *J. Ver Hoef 135*, 18 July 1979 (ALA); Anchorage Quad: Hatcher Pass, 61°47.0′ N 149°17.0′ W, *C.L. Williams 89110*, 4 August 1989 (ALA)). It is considered rare in Alaska (G1 S1). Map 148.

Potentilla litoralis Rydb. (*P. virgulata* Nels., *P. pennsylvanica* var. *virgulata* (A. Nels.) T. Wolf), Pennsylvania Cinquefoil — Chugach Mountains: scattered in *Dryas* dwarf shrub tundra on open gravel bars, Tana River floodplain, 335 m, 61°11′ N 142°51′ W, *Parker & Gracz 6811*, 9 August 1996. Mentasta Mountains: dry rocky soil on steep S slope, between Platinum and Totschunda Creek, 1280 m, 62°27.83′ N 142°46.23′ W, *A.R. Batten 98-13*. Nutzotin Mountains: scattered in open low shrub birch, disturbed sandy soil of airstrip, Horsfeld airstrip, 1097 m, 62°1′ N 141°11′ W, *Parker & Gracz 6893*, 12 August 1996. St. Elias Mountains: occasional in S-facing gravels and open ground with seral herbs, ridge between Logan and Walsh Glaciers, 1951 m, 60°53.94′ N 141°6.75′ W, *C. Roland 95-154*, 11 July 1995; occasional on dry, disturbed SE-facing gravel slopes, Mt. Chitina, 2073 m, 60°57.74′ N 141°17.33′ W, *C. Roland 95-212*, 15 July 1995.

This North American arctic-alpine species was collected on the upper Chitina River (61°1.32 N 141°37.69 W; *H.M. Laing 113*, 1925 (CAN) (Porsild 1939, Hultén 1941–1950)) and near Slana (62°36.10′N 143°45.97W; *Viereck & Richter 10378*, 26 July 1980 (ALA)). The specimens cited above extend its range 150 km east into the Nutzotin Mountains and 70 km west down the Chitina River. These new collections connect the distribution between the Kenai Peninsula 404 km to the west (Hultén 1968), the Alaska Range 288 km to the north (Hultén 1968) and the Yukon Territory 41 km to the east (Cody 1996). Map 149.

Potentilla rubricaulis Lehmann (*P. hookeriana* Lehm. ssp. *hookeriana* var. *furcata* (Pors.) Hult.), Rocky Mountain Cinquefoil — Chugach Mountains: rare in *Dryas*-graminoid tundra, between Granite and Lime Creeks, 1829 m, 61°0.22′ N 141°51.1′ W, *C. Roland 96-751*, 28 July 1996.

This species is North American with an arctic-alpine distribution. The locality cited above is 900 km south of its range in northern Alaska (Philip Smith Mountain Quad: Mt. Hultén, 68°27.0′ N 149°18.0′ W, *D.F. Murray 9019*, 2 August 1977 (ALA)) and 235 km east of collections in the Yukon Territory (Cody 1996). Map 150.

Fabaceae

Astragalus adsurgens Pall. ssp. *viciifolius* (Hult.) Welsh (*A. adsurgens* var. *tananaicus* (Hultén) Barneby) — Mentasta Mountains: semi-prostrate mats on gravel bar, Nabesna River at Totschunda Creek, 725 m, 62°26.94′ N 42°40.8′ W, *C. Roland 96-251*, *M. Cook 96252*, 23 June 1996 (ALA). Nutzotin Mountains: mixed forb herbaceous vegetation in gravel, Chisana airstrip, 1006 m, 62°4.16′ N 142°2.84′ W, *M. Duffy 92190*, 9 July 1992.

This Alaska-Yukon endemic with a boreal-montane distribution had been collected near Chitina (Kotsina River floodplain, 61°32.23′ N 144°23.63′ W, *J. Major s.n.*, 31 July 1980 (ALA); Chitina River Campground, 61°31.06′N

149. Potentilla litoralis

150. Potentilla rubricaulis

151. Astragalus adsurgens ssp. *viciifolius*

152. Astragalus eucosmus ssp. *sealei*

144°23.67′ W, *Khokhryakov et al. 6102*, 8 July 1981 (ALA)). The new collections cited above are 140 km north of the Chitina collections and extend the range of this species into the Mentasta and Nutzotin Mountains. The closest collections to those cited above are 85 km to the north at mile 1247 on the Alaska Highway (*J.P. Anderson 9188* (S) (Hultén 1946)) and 137 km to the east in the Yukon Territory. This subspecies is known only from Alaska and the Yukon as indicated on the distribution map, whereas *A. adsurgens* sensu lat is widely distributed in the western plains and mountains of the United States, Canada and in Asia. Map 151.

Astragalus eucosmus Robins. ssp. *sealei* (Lepage) Hultén, Elegant Milk-Vetch — MENTASTA MOUNTAINS: scattered in stony tundra on limestone, ridge between Little Jack and Trail Creeks, 1615 m, 62°36.05′ N 143°17.63′ W, *C. Roland 95-019*, 7 June 1995. ST. ELIAS MOUNTAINS: scattered on SE-facing limestone rubble slope, Mt. Natazhat, 1716 m, 61°35.38′ N 141°1.83′ W, *C. Roland 95-062*, 19 June 1995.

There were two stations of this Alaska-Yukon endemic mapped by Hultén (1968) in the Park. The station at Slana may have been Hultén's collection since he collected in this vicinity in 1960. We have not been able to find data for the station in the central Wrangells which could have been W. L. Poto's from the 1902 U.S.G.S. expedition (Mendenhall and Schrader 1903; Poto 1902*). However, Hultén included the rest of Poto's collections in his 1941-1950 flora so it seems unlikely that he would have missed this specimen. The specimen from Mt. Natazhat cited above is 195 km east of the previous collections and extends the range of this species into the St. Elias Mountains. Our collections are 213 km southeast of a station in the Alaska Range (Healy Quad: 63°24.0′ N 148°56.0′ W, *G. Smith 2201*, 4 September 1953 (ALA)) and 178 km west of a station in the Yukon Territory (Cody 1996). *Astragalus eucosmus* sensu lat ranges from Labrador, Newfoundland, Alaska and the Yukon Territory, south to Maine and west to Utah and Colorado. Map 152.

Astragalus harringtonii (Rydb.) Hultén (*A. robbinsii* (Oakes) Gray var. *harringtonii* (Rydb.) Barneby, *A. robbinsii* (Oakes) Gray ssp. *harringtonii* (Rydb.) Hult.), Harrington Milk-vetch — CHUGACH MOUNTAINS: occasional near edge of forest in eroding soils, Tana Dunes, 488 m, 61°6.19′ N 142°55.03′ W, *C. Roland 94-180*, 7 July 1994. NUTZOTIN MOUNTAINS: rare on N-facing limestone talus slope in moist red silt clay, Cooper Pass, 1942 m, 62°17.16′ N 142°31.44′ W, *M. Cook 94353*, 24 July 1994. WRANGELL MOUNTAINS: few in poplar woodland, Nabesna River, 884 m, 62°12.63′ N 142°52.28′ W, *M. Cook 96173B*, 6 June 1996.

This species is endemic to Alaska with a Pacific coastal distribution. There were two stations adjacent to the Park mapped in Hultén 1968, one at Chitina and one at Yakutat Bay (59°47.35′N 139°33.69′W, *E.P. Walker 2416*, 1914 (US)). The specimens cited above extend its range 111 km north into the Wrangell Mountains, 130 km north into the Nutzotin Mountains and 91 km south into the Chugach Mountains and document the northern extent of its range. Map 153.

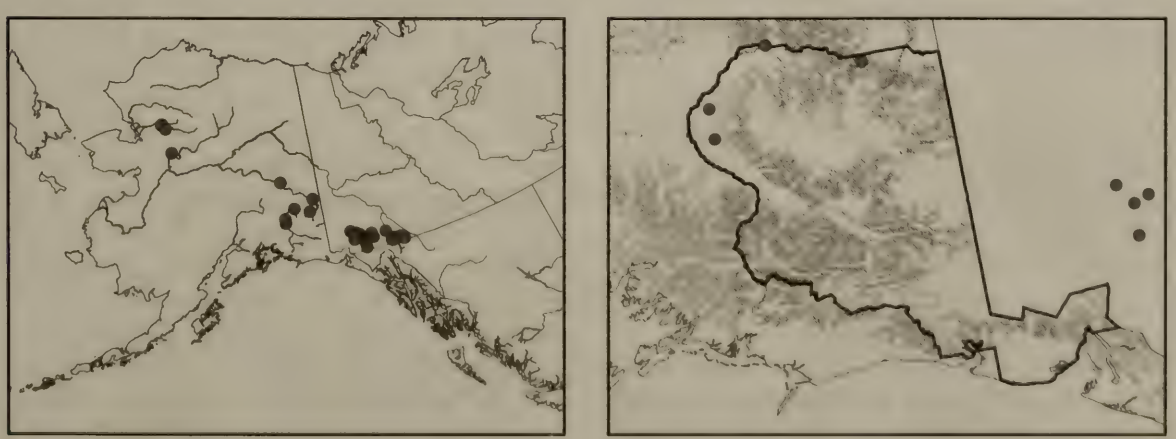
Astragalus nutzotinensis Rousseau, Nutzotin's Milkvetch — CHUGACH MOUNTAINS: scattered in dry, loose marble gravel on SW-facing slope, ridge between Granite and Lime Creeks, 1829 m, 61°0.22′ N 141°51.1′ W, *C. Roland 96-742*, 28 July 1996; few on limestone outcrops and in patches of *Dryas*, ridge between Canyon, Pass and Tenas Creeks, 1682 m, 61°24.28′ N 144°21.61′ W, *Cook & Losso 96327*, 8 July 1996; locally common in sandy soil at contact between marble unit and darker crystalline rock on moderate W-facing slope, ridge between Canyon and Pass Creeks, 1463 m, 61°24.35′ N 144°20.8′ W, *Roland & D'Auria 96-441*, 9 July 1996. MENTASTA MOUNTAINS: scattered in limestone gravel on barren slope, ridge between Lost and Platinum Creeks at peak 5240, 1646 m, 62°34.58′ N 143°5.58′ W, *Cook & Roland 94334*, 23 July 1994; rare in fine, needle-like argillite scree on steep, E-facing barren slope, ridge between Lost and Platinum Creeks at peak 5240, 1646 m, 62°34.58′ N 143°5.58′ W, *C. Roland 94-270*, 23 July 1994; in runnels of soil in fine limestone scree, ridge between Little Jack and Trail Creeks, 1615 m, 62°36.05′ N 143°17.63′ W, *C. Roland 95-008*, 6 June 1995; upper Trail Creek, 1341 m, 62°37.09′ N 143°16.06′ W, *Potkin & Leggett 95-060A*, 28 July 1995; scattered on moderate slope of calcareous gravel, Nabesna River at Totschunda Creek, 1280 m, 62°27.63′ N 142°12.44′ W, *C. Roland 96-286*, 24 June 1996. ST. ELIAS MOUNTAINS: occasional in limestone scree below SE-facing cliffs, ridge between Dan & Copper Creeks, 1554 m, 61°21.56′ N 142°26.43′ W, *C. Roland 94-237*, 14 July 1994; common in dry screes and ridges, Mt. Chitina, 2073 m, 60°57.74′ N 141°17.33′ W, *C. Roland 95-222*, 16 July 1995. WRANGELL MOUNTAINS: moist sand and cobbles, confluence of Copper Creek and Kotsina River, 610 m, 61°42.34′ N 144°3.6′ W, *C.R. Meyers 84-125*, 27 July 1984; adjacent to limestone outcrop on gentle E-facing slope of saddle, Alice Peak, 1600 m, 61°39.8′ N 144°6.63′ W, *C.R. Meyers 84-144*, 1 August 1984; rare in barren cobbles of river bar on W bank of Nabesna River at Monte Cristo Creek, 853 m, 62°13.71′ N 142°54.14′ W, *C. Roland 96-150*, 18 June 1996; E-facing shaley scree, Nikolai Mine, 1695 m, 61°27′ N 142°39′ W, *Batten & Barker 96-087*, 24 July 1996; rare in loose gravel on barren SW-facing slope, volcanic ridge 6.4 km E of Snyder Peak, 1524 m, 62°4.47′ N 144°30.51′ W, *C. Roland 96-381*, 5 July 1996; scattered in sandy exposed area on ridge above cliffs, plateau between Long Glacier and the Cheshnina River, 1399 m, 61°48.04′ N 144°6.27′ W, *M. Cook 96708*, 8 August 1996; occasional in moist sandy gravel on an unstable slope, plateau between Long Glacier and the Cheshnina River, 1399 m, 61°48.04′ N 144°6.27′ W, *M. Cook 96710*, 8 August 1996.

This Alaska-Yukon endemic with an arctic-alpine distribution was known from seven localities in the northern

153. Astragalus harringtonii

154. Astragalus nutzotinensis

155. Astragalus williamsii



156. Lupinus kuschei

St. Elias and Wrangell Mountains: Guerin Glacier (61°37.42′N 141°4.38′W, *D. F. Murray 2086*, 4 August 1968 (ALA)); Sheep Glacier (61°42.48′N 141°38.59′W, *D. F. Murray 2241*, 15 August 1968 (ALA)); Skolai Pass (61°37.25′N 141°58.77′W, *D. F. Murray 711* (CAN) (Murray 1968); *R. Scott 1631, 1746*, 23 June 1967 (MICH) (Scott 1968)); Chitistone Pass (61°36.91′N 141°54.78′W, *R. Scott 1631*, 23 June 1967 (ALA) (Scott 1968); *D. F. Murray 711*, 1 July 1967 (ALA) (Murray 1968)); upper Chitina River (61°1.57′N 141°37.63′W (Hultén 1968)); Nugget Creek (61°37.51′N 143°43.63′W, *E. Muphy s.n.*, 1978 (ALA)), and Nabesna (62°25.17′N 143°3.11′W (Hultén 1968)). Our collections extend its range into the western Wrangell, Mentasta and Chugach Mountains. It is considered rare in the Yukon Territory by Douglas et al. (1981). Map 154.

Astragalus williamsii Rydb., Williams' Milkvetch — MENTASTA MOUNTAINS: rare in open white spruce/poplar forest at toe of slope, Totschunda Creek, 1280 m, 62°27.63′ N 142°12.44′ W, *C. Roland 96-263*, 24 June 1996; abundant at margin of floodplain white spruce forest, Nabesna River, 488 m, 62°47.9′ N 142°9.97′ W, *C. Roland 96-301*, 25 June 1996.

This Alaska-Yukon endemic has a limited distribution in the state. The collections cited above extend its range 70 km south into the Mentasta Mountains from a station along the Slana-Tok Highway (Clearwater Creek, 62°59.38′N 143°20.35′W, *Anderson & Brown 9224* (S) (Hultén 1941-1950)). Map 155.

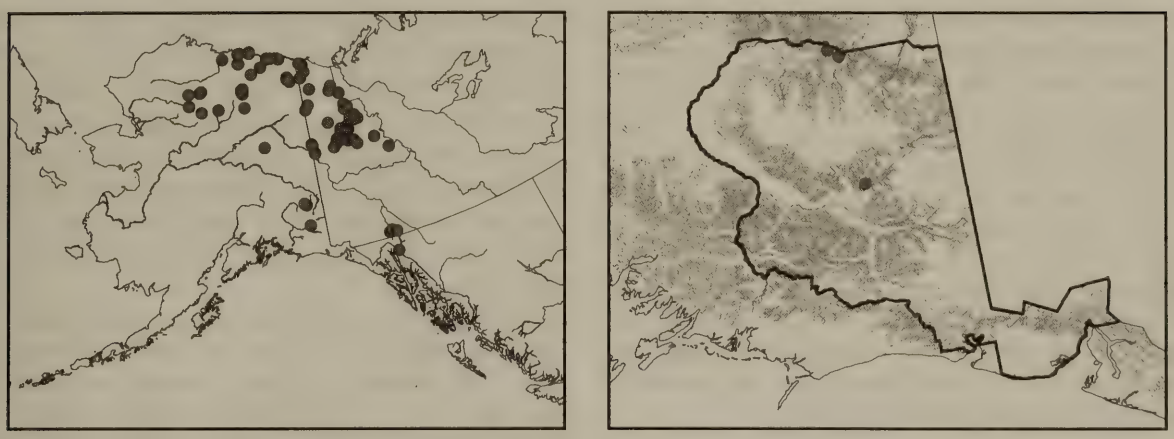
Lupinus kuschei Eastw., Yukon Lupine — MENTASTA MOUNTAINS: occasional in sandy areas of gravel bar, Totschunda Creek floodplain, 725 m, 62°26.94′ N 42 °40.8′ W, *C. Roland 96-255*, 23 June 1996. WRANGELL MOUNTAINS: gravel roadside, km 2.4 Nabesna Road, 655 m, 62°41.84′ N 143°55.1′ W, *M. Duffy 91014*, 22 June 1991; sparsely vegetated dry forb-graminoid herbaceous meadow, Sanford Dunes, 686 m, 62°1.59′ N 145°0.12′ W, *M. Duffy 92200*, 10 July 1992.

This Alaska-Yukon endemic with a boreal montane distribution is rare in Alaska (G3 S2) and of limited distribution in the Yukon Territory (Cody 1996). The specimens cited above extend its range 195 km into the Wrangell Mountains and 65 km into the Mentasta Mountains from a station along the Alaska Highway at mile 1257 (Lakeview Campground, 62°50.0′ N 142°00.0′ W, *H. Schmuck s.n.*, 16 August 1962 (ALA)). Map 156.

Oxytropis campestris (L.) DC. ssp. *jordalii* (Pors.) Hult., Late Yellow Locoweed — MENTASTA MOUNTAINS: common in exposed, rocky site on SE-facing slope, Soda Lake, 1173 m, 62°32.36′ N 142°53.98′ W, *C. Roland 94-246B*, 21 July 1994, *M. Cook 94319*, 22 July 1994 (ALA); common in exposed, rocky site on SE-facing slope, Totschunda Creek, 1280 m, 62°27.63′ N 142°12.44′ W, *C. Roland 96-272*, 24 June 1996. WRANGELL MOUNTAINS: dry rocky soil on ridge crest, Nikolai Mine, 1695 m, 61°27′ N 142°39′ W, *Batten & Barker 96-061*, 24 July 1996.

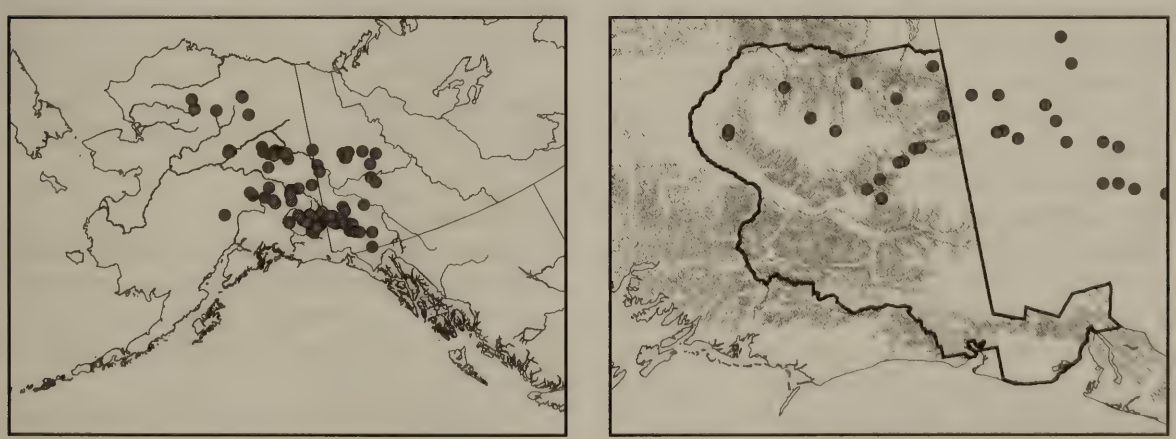
This species is amphiberingean with an arctic-alpine distribution. The collections cited above extend its range 314 km south into the Mentasta Mountains from a station in the Charley River Quad (vic. VABM Nation, 65°16.0′ N 141°08.0′ W, *Lipkin & Cook s.n.*, 14 June 1993 (ALA)) and 277 km northwest of a station near Skagway (Hultén 1968). Map 157.

Oxytropis huddelsonii Pors., Huddelson's Locoweed — CHUGACH MOUNTAINS: solifluction soil, mesic tundra, Juniper Island, Granite Range, 1346 m, 60°36.17′ N 142°14.96′ W, *C. Roland 94-216*, 12 July 1994; scattered in gravel, SW-facing slope, Granite Creek, 1829 m, 61°0.22′ N 141°51.1′ W, *C. Roland 96-744*, 28 July 1996; boulder field, in mat of *Rhacomitrium*, E. Fork Kiagna River, Granite Range, 1487 m, 60°59.5′ N 142°1′ W, *Batten & Barker 96-321*, 29 July 1996 (ALA). MENTASTA MOUNTAINS: Soda Lake, 1173 m, 62°32.36′ N 142°53.98′ W, *C. Roland 94-259C*, 22 July 1994; scattered in calcareous gravel, Totschunda Creek, 1280 m, 62°27.63′ N 142°12.44′ W, *C. Roland 96-287*, 24 June 1996; rare in dry, gravelly tundra, Devil's Mountain, 1530 m, 62°25.62′ N 142°53.93′ W, *C. Roland 96-360D*, 3 July 1996. NUTZOTIN MOUNTAINS: moist tundra, NW-facing slope, 4 km E of Wiki Peak, 1585 m, 61°55.98′ N 141°8.02′ W, *C. Roland 94-119B*, 23 June 1994; occasional on steep S-facing scree slope, Horsfeld Creek, 1768 m, 62°2.88′ N 141°13.18′ W, *M. Cook 94146*, 24 June 1994; scattered in gravel areas, S-facing alpine meadow, Carden Hills, 1311 m, 62°18.44′ N 141°11.55′ W, *C. Roland 94-140B*, 26 June 1994; common in dry graminoid tundra, W-facing slope, Rock Lake, 1119 m, 61°48.7′ N 141°16.57′ W, *C. Roland 96-032*, 6 June 1996; occasional in tundra and dry gravels, Wiki Creek, 1411 m, 61°54.46′ N 141°10.68′ W, *C. Roland 96-061*, 6 June 1996. WRANGELL MOUNTAINS: N-facing scree slope, Lime Creek, 1707 m, 61°53.27′ N 141°37.05′ W, *M. Cook 92112*, 7 July 1992; basalt rubble, Cone Ridge, 2073 m, 62°8.21′ N 143°18.47′ W, *M. Cook 94401*, 25 July 1994; common in mesic tundra, Crystalline Hills, 1585 m, 61°23.59′ N 143°31.85′ W, *C. Roland 95-233*, 18 July 1995; *Dryas* dwarf scrub tundra, Lakes Plateau, 1890 m, 62°4.4′ N 143°23.5′ W, *Potkin & Leggett 95-113*, 30 July 1995; occasional in morainal deposits, Ruddy Mountain, 1615 m, 62°4.61′ N 144°46.39′ W, *C. Roland 96-329*, 2 July 1996; dry tundra, Nikolai Pass, 1280 m, 61°26′ N 142°40′ W, *Batten & Barker 96-013*, 23 July 1996 (ALA); dry tundra, Nikolai Pass, 1280 m, 61°26′ N 142°40′ W, *Batten & Barker 96-049*, 23 July 1996; common in tundra, Grotto Creek, 1847 m, 61°30.56′ N 142°24.79′ W, *C. Roland 96-647*, 23 July 1996; moist scree, VABM Sentinel, W of Nizina Glacier, 1829 m, 61°39′ N 142°32′ W, *Batten & Barker 96-117*, 24 July 1996 (ALA); scattered in volcanic sand, Cheshnina Plateau, 1399 m, 61°48.04′ N 144°6.27′ W, *M. Cook 96712*, 5 August 1996.

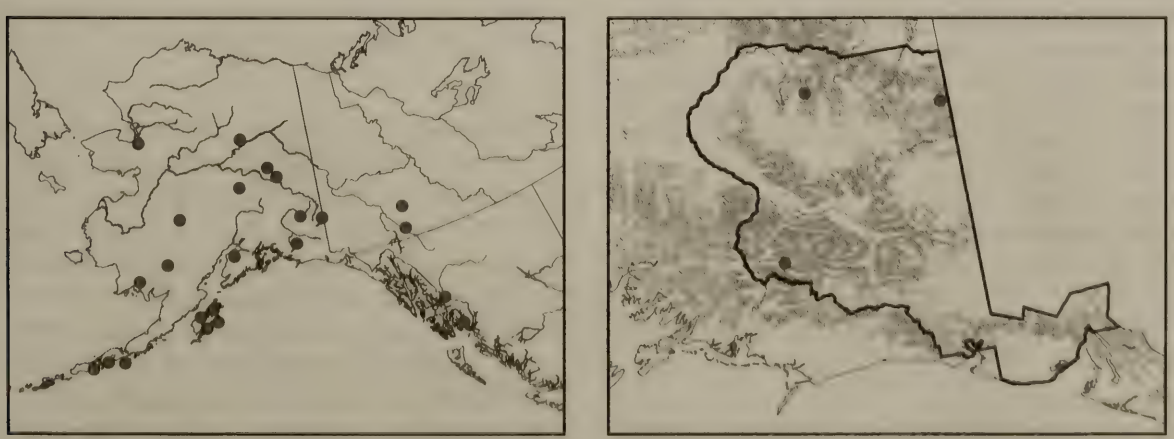


157. *Oxytropis campestris* ssp. *jordalii*

158. *Oxytropis huddelsonii*



159. *Oxytropis scammaniana*



160. *Callitriche anceps*

This Alaska-Yukon endemic with a cordilleran distribution had been collected at four localities in the Wrangell-St. Elias Mountains: Russell Glacier (61°41.93′N 141°45.36′W, *D. F. Murray 2168*, 11 August 1968 (ALA)); Guerin Glacier (61°37.42′N 141°4.38′W, *D. F. Murray 2037*, 3 August 1968 (ALA)); Chitistone Pass (61°37′ N 141°58′ W, *D. F. Murray 712* (CAN) (Murray 1968)); and Chetaslina River headwaters (61°59.36′N 144°20.24′W, *R. Saltmarch PA21*, 11 July 1978 (ALA)). The specimens cited above extend its range 114 km south into the Bagley Icefield, 71 km south into the Chugach Mountains, 96 km north into the Mentasta Mountains and 89 km north into the Nutzotin Mountains. This species is considered rare in Alaska (G3 S2S3). Map 158.

Oxytropis scammaniana Hultén, Scamman's Oxytrope — NUTZOTIN MOUNTAINS: few on S-facing rubble slope, Wiki Creek, 1411 m, 61°54.46′ N 141°10.68′ W, *M. Cook 96095*, 7 June 1996; *Dryas* dwarf scrub tundra, Gold Hill, 1615 m, 62°6.88′ N 141°54.12′ W, *M. Cook 89930*, *C. Roland 96-071*, 6 July 1989; scattered in gravel on S-facing subalpine meadow, Carden Hills, 1311 m, 62°18.44′ N 141°11.55′ W, *C. Roland 94-139*, 26 June 1994. WRANGELL MOUNTAINS: *Dryas* tundra, Lakes Plateau, 1890 m, 62°4.4′ N 143°23.5′ W, *Potkin & Leggett 95-138*, 31 July 1995; occasional in bare mineral soil, Cooper Pass, 1942 m, 62°17.16′ N 142°31.44′ W, *M. Cook 94356*, 24 July 1994; alpine tundra, Nabesna Glacier, 1768 m, 61°56.6′ N 143° W, *M. Duffy 92119*, 26 June 1992; dry rocky soil on ridge, Nikolai Mine, 1695 m, 61°27′ N 142°39′ W, *Batten & Barker 96-062*, 24 July 1996; occasional in morainal deposits, Ruddy Mountains, 1615 m, 62°4.61′ N 144°46.39′ W, *C. Roland 96-330*, 2 July 1996; scattered in mesic tundra, Grotto Creek, 1661 m, 61°30.56′ N 142°24.79′ W, *C. Roland 96-656*, 23 July 1996; scattered in crevices of basalt on ledge, Black Mountain, 1481 m, 62°20.85′ N 143°44.9′ W, *M. Cook 95154*, 2 July 1995; *Dryas* tundra, Upper Sanford River, 62°2.76′ N 144°47.91′ W, *M. Duffy 91022*, 23 June 1991. ST. ELIAS MOUNTAINS: common in N-facing tundra, Lime Butte, 1554 m, 61°21.56′ N 142°26.43′ W, *C. Roland 94-232A*, 13 July 1994.

This species is an Alaska-Yukon endemic with an arctic-alpine distribution. It had been collected at four localities in the Wrangell-St. Elias Mountains: Chitistone Pass (Scott 1968); Skolai Pass (Murray 1968); Sheep Glacier (*D.F. Murray 2260*, 15 August 1968 (ALA)); and Russell Glacier (*D.F. Murray 2187*, 11 August 1968 (ALA)). The collections cited above extend its range 154 km west into the western Wrangell Mountains, 89 km north into the Nutzotin Mountains and connect the distribution 139 km to the northwest in the Alaska Range (Tangle Lakes, 63°03.0′ N 146°01.0′ W, *G. Smith 2063*, 21 August 1953 (ALA)) with the range 33 km to the east in the Yukon Territory (Cody 1996). Map 159.

CALLITRICHACEAE

Callitriche anceps Fern. (*Callitriche heterophylla* ssp. *heterophylla* Pursh.) — CHUGACH MOUNTAINS: beaver pond, Three Mile Canyon, 610 m, 60°58.37′ N 144°8.44′ W, *M. Duffy 91148*, 19 August 1991. NUTZOTIN MOUNTAINS: submerged in shallow water of small remnant pond in kettle depression, Braye Lakes, 1097 m, 62°2′ N 141°9′ W, *Parker & Gracz 6887*, 11 August 1996. WRANGELL MOUNTAINS: submerged in slow moving creek, vic. Grizzly Lake, 62°13.92′N 143°22.17′W, *Cook & Allen 3559*, 26 July 2000.

This North American boreal montane aquatic plant is considered rare in the Yukon Territory (Douglas et al. 1981). The stations cited above extend its range 347 km east into the Chugach Mountains from a station on the Kenai Peninsula (Hultén 1968), 252 km south into the Wrangell Mountains and 338 km southeast into the Nutzotin Mountains from a collection in the Big Delta Quad (Birch Lake, 64°20.0′ N 146°40.0′ W, *C. Parker 2200*, 29 Aug 1989 (ALA)). Map 160.

Callitriche hermaphroditica L., Northern Waterstarwort — NUTZOTIN MOUNTAINS: lake margin, 0.5 m deep, mixed freshwater herbaceous, Ptarmigan Lake, 1079 m, 61°51.51′ N 141°10.78′ W, *J. Barnes 96-252*, 8 August 1996. WRANGELL MOUNTAINS: scattered in 50 cm of water, rooted in rocky floor of small, shallow pond, Fish Creek, 1067 m, 62°16.92′ N 142°58.99′ W, *C. Roland 95-284*, 29 July 1995.

This circumpolar boreal montane species has a spotty distribution throughout its range. The specimens cited above extend its range 99 km south into the Nutzotin Mountains from a station along the Alaska Highway near the Yukon border (Nabesna Quad: Scottie Creek, 62°41.0′ N 141°05.0′ W, *L. Vining 61*, 27 August 1979 (ALA)) and 179 km southeast into the Wrangell Mountains from a collection at Tangle Lakes (Mt. Hayes Quad: 63°03.0′ N 146°01.0′ W, *G. Smith 2090*, 22 August 1953 (ALA)). Map 161.

BALSAMINACEAE

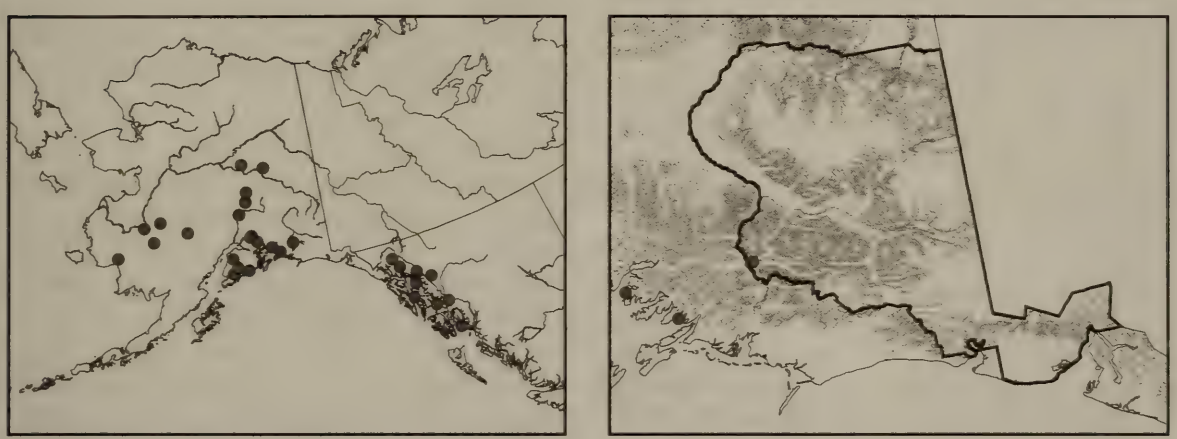
Impatiens noli-tangere L., Western Touch-Me-Not — CHUGACH MOUNTAINS: Rare in the shade of tall alder scrub, confluence of Bremner and Copper Rivers, 152 m, 61°0.94′ N 144°40.76′ W, *C. Roland 96-597*, 17 July 1996.

The locality cited above of this incompletely circumpolar widespread species, extends its range 87 km east into the Chugach Mountains from a station near Cordova (Hultén 1968). The closest station to the east is 550 km near Skagway (Hultén 1968). Map 162.

VIOLACEAE

Viola adunca J.E. Smith, Hook-spur Violet — ST. ELIAS MOUNTAINS: moist herbaceous patch among birch shrubs, Short River, 503 m, 61°5.35′ N 141°56.3′ W, *Parker & Duffy 6702*, 6 August 1996. CHUGACH MOUNTAINS: occasional in moss of meadow, Nerelna Creek Plateau, 1372 m, 61°26.66′ N 144°17.69′ W, *M. Cook 96302*, 7 July 1996; herbaceous meadow, Upper Golconda, 1311 m, 61°2.8′ N 143°25.64′ W, *L. A. & E. G. Viereck 11072*, 7 July 1996; W-facing heath, Juniper Island, 1291 m, 60°36.24′ N 142°21.69′ W, *C. Roland 94-218A*,

161. Callitriche hermaphroditica



162. Impatiens noli-tangere

163. Viola adunca

164. Viola biflora

12 July 1994; mesic tundra slope, Goat Creek, 1487 m, 60°59.5′ N 142°1′ W, *Batten & Barker 96-205*, 27 July 1996.

This violet is North American with a boreal-montane distribution. The collections cited above extend its range 103 km south into the Chugach Mountains from a collection on Bonanza Ridge in the Wrangell Mountains (Nordell & Schmitt 1977) and connect the range 356 km to the west in the Anchorage Quad (61°01.0′ N 149°44.0′ W, *L.L. Hawkins s.n.*, 12 June 1976 (ALA)) with the range in the Yukon Territory 207 km to the east (Cody 1996). Map 163.

Viola biflora L., Twoflower Violet — WRANGELL MOUNTAINS: E-facing rubble slope, Jaegar Mesa, 1893 m, 62°15.9′ N 143°1.24′ W, *Moran & Roland 95-34*, 1 July 1995; few, in *Rhacomitrium* between boulders along ridge, Black Mountain, 1481 m, 62°20.85′ N 143°44.9′ W, *Cook & Beck 95142*, 1 July 1995; few under boulders on rubble slope, Fish Creek , 1067 m, 62°16.92′ N 142°58.99′ W, *M. Cook 95320*, 27 July 1995; abundant on east and W-facing morainal slopes, Grizzly Lake, 1108 m, 62°19.51′N 143°9.24′W, *Allen & Cook 00-067*, 25 July 2000.

This violet has an incompletely circumpolar distribution throughout arctic-alpine regions and is considered rare in the Yukon Territory (Douglas et al. 1981). The four localities cited above extend its range 151 km south into the Wrangell Mountains from the Alaska Range (Mt. Hayes Quad: 63°38.0′ N 144°44.0′ W, *L.A. Spetzman 183*, 25 June 1957 (ALA)) and 261 km east from the Talkeetna Mountains (62°31.0′ N 149°11.0′ W, *E. Helmstetter 213-79*, 29 July 1979 (ALA)). Map 164.

Viola selkirkii Pursh, Great-spurred Violet — WRANGELL MOUNTAINS: growing in alder-spruce stand, near Angle Station, Bonanza Ridge, 975 m, 61° 30.70′ 142° 49.85′, *G. Frost s.n.*, 1 June 1998 (ALA).

This boreal-montane violet is circumpolar with large gaps. The locality cited above from the Wrangell Mountains connects its range 180 km to the southwest in the Valdez Quad (Mile 14 Richardson Highway, *I.W. Ailes 17* (ALA)) with collections 473 km to the southeast near Skagway (Hultén 1968) and 615 km to the northeast in the Yukon Territory (Cody 1996). It is considered rare in Alaska (G5? S3) and in the Yukon Territory (Douglas et al. 1981). Map 165.

ONAGRACEAE

Epilobium lactiflorum Haussk, White-Flower Willowherb — CHUGACH MOUNTAINS: forb herbaceous meadow, Juniper Island, 1291 m, 60°36.24′ N 142°21.69′ W, *M. Cook 94283*, 13 July 1994. ST. ELIAS MOUNTAINS: alpine mesic forb herbaceous slope, Blossom Island, 732 m, 59°59.97′ N 140°5.1′ W, *M. Cook s.n.*, 21 August 1987. WRANGELL MOUNTAINS: clumped in mesic dry creek bed, Nadina Glacier, 1768 m, 62°2.85′ N 144°41′ W, *M. Cook 94420*, 30 August 1994; in *Aulocomnium* moss in stream, Chetaslina Ridge, 1615 m, 61°56.51′ N 144°25.93′ W, *M. Cook 94494*, 17 August 1994.

This species is amphiatlantic with a boreal-montane distribution. It was collected by O. Nordell and A. Schmitt on Bonanza Ridge in the southern Wrangell Mountains (Nordell and Schmitt 1977). The Wrangell Mountain collections cited above extend the range of this species 116 km into the Western Wrangells and the St. Elias Mountain collections connect the range 315 km to the west near Cordova (Schwan Glacier, 60°58.0′ N 145°00.0′ W, *C. Parker 1766*, 12 August 1986 (ALA)) with a station near Haines (Cody 1996). Map 166.

Epilobium luteum Pursh, Yellow Willowherb — ST. ELIAS MOUNTAINS: mesic mixed herbaceous alpine slope, Samovar Hills, 549 m, 60°8.11′ N 140°39.55′ W, *M. Cook 87-143*, 23 August 1987.

This species is North American with a Pacific coastal distribution. The collection cited above connects the range 330 km to the west near Cordova (Hultén 1968) with a station at Yakutat 110 km to the east (Hultén 1968). Map 167.

HIPPURIDACEAE

Hippuris montana Ledeb., Mountain Marestail — GULF OF ALASKA: dwarf scrub/mixed forb alpine tundra, Icy Bay, 579 m, 60°5.83′ N 141°27.3′ W, *K.A. Beck s.n.*, 10 August 1987; tall forb meadow, Chaix Hills, 1550 m, 60°3.18′ N 141°5.1′ W, *M. Duffy 92213*, 17 August 1992. WRANGELL MOUNTAINS: mud along shore of pond, 0.8 km east of Lake 2910′, Copper River, 823 m, 62°26.35′ N 143°40.77′ W, *M. Cook 96744*, 8 August 1996.

This North American Pacific coastal species is known from one locality in the Yukon Territory and should be added to the list of rare plants for the Territory (Cody 1994, 1996). The specimens cited above from Icy Bay and Chaix Hills connect its coastal range 394 km to the west at Thum Bay (*W.J. Eyerdam 3301, 3537*, 31 July 1931 (UC, S) (Hultén 1946)) with a station 357 km to the east near Haines (Hultén 1968). The station cited above from the Wrangell Mountains extends the range of this species 297 km to the southeast from a station near Denali National Park (Hultén 1968) and is 298 km north of the coastal localities in the Park. Map 168.

HALORAGACEAE

Myriophyllum verticillatum L., Whorlleaf Watermilfoil — WRANGELL MOUNTAINS: 1 m deep water, bog 2.5 km NW of Billy Lake, 614 m, 61°27.99′ N 143°56.38′ W, *C. Roland 94-323*, 10 August 1994.

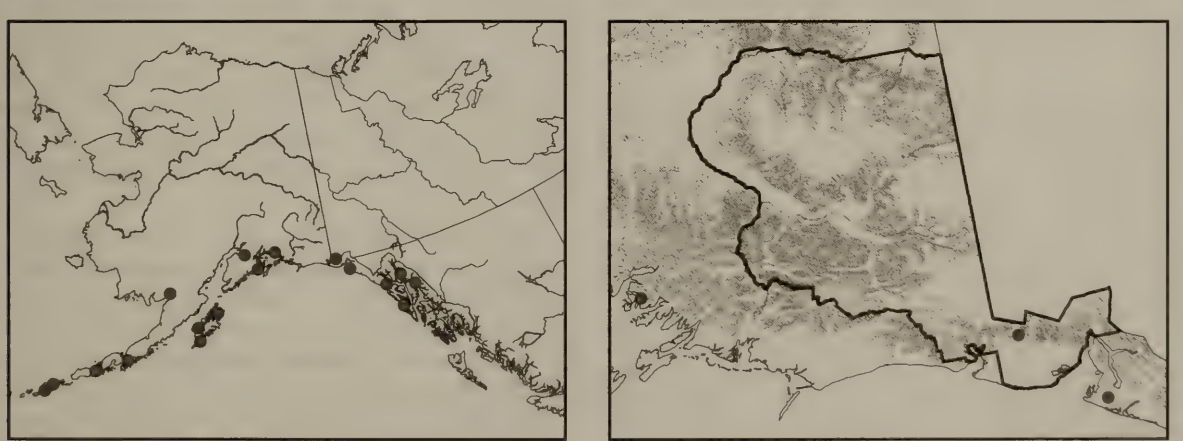
This species is incompletely circumpolar and disjunct from temperate zones. It is rare in Alaska (G5 S3) and the Yukon Territory (Douglas et al. 1981). The specimen cited above extends its range 238 km east from the Anchorage Quad (Otter, 61°17.53′ N 149°44.17′ W, *Duffy & Tande 1019*, 3 August 1994 (ALA)) and connects the range 363 km to the east near Haines Junction in the Yukon Territory (Cody 1996). Map 169.

APIACEAE

Cicuta maculata L. var. *angustifolia* Hook. (*C. douglasii* (DC.) Coult. & Rose), Spotted Water Hemlock — GULF OF ALASKA: wet graminoid meadow, Yahtse River mouth, Malaspina Forelands, 30 m, 59°50.22′ N 141°13.67′ W, *M. Duffy 92237*, 19 August 1992.

165. Viola selkirkii

166. Epilobium lactiflorum



167. Epilobium luteum

168. Hippuris montana

This specimen connects the Pacific Coastal distribution of this North American species 186 km to the west at Cape St. Elias (59°56.0′ N 144°23.0′ W, *Cunningham & Stanford 228-78*, 21 June 1978 (ALA)) with stations in the vicinity of Yakutat and the Ankow River 89 km to the east (*F. Funston 71*, 1892 (CAN, UC) (Coville and Funston 1896; Hultén 1946); *C.V. Piper 42, 82*, 1904 (US) (Hultén 1946)). This species is considered rare in the Yukon Territory (Douglas et al. 1981). Map 170.

Ligusticum scoticum L. ssp. *hultenii* (Fern.) Calder & Taylor, Hultén's Sea-lovage — GULF OF ALASKA: closed tall willow-alder scrub, 0.2 km N of Schooner Beach, Malaspina Forelands, 30 m, 59°46.52′ N 140°1.45′ W, *K.A. Beck s.n.*, 9 August 1987.

This species is amphiberingian with a North Pacific Coastal distribution. The specimen cited above connects its range 253 km to the west at Cape St. Elias (59°56.0′ N 144°23.0′ W, *Cunningham & Stanford 198-78*, 16 June 1978 (ALA)) with a station in the vicinity of Yakutat 30 km to the east (*F. Funston 70*, 1892 (US,UC); *Trelease & Saunders 4530, 4531*, 1899 (US) (Hultén 1946)). Map 171.

Osmorhiza depauperata Phil., Bluntseed Sweetroot — CHUGACH MOUNTAINS: open cottonwood forest, Jackson Creek, 61°7.38′ N 144°53.17′ W, *M. Duffy 91133*, 15 August 1991.

This North American boreal-montane umbel is rare in the Yukon Territory (Douglas et al. 1981). The locality cited above represents the northern extent of its range and connects the range 128 km to the west near Valdez (Hultén 1968) with the range 582 km to the southeast near Gustavus (Hultén 1968). Map 172.

ERICACEAE

Cassiope mertensiana (Bong.) D. Don, White Mountain Heather — CHUGACH MOUNTAINS: mountain heath tundra on scoured bedrock, ridge east of Falls Creek falls, 1097 m, 61°9.2′ N 144°22.31′ W, *M. Duffy 91116*, 12 August 1991.

This species is North American with a Pacific coastal distribution. The locality cited above connects a station 939 km to the southwest in the Chignick Quad (56°18.0′ N 158°24.0′ W, *J. Dodge s.n.*, 24 July 1985 (ALA)) with stations 489 km to the southeast near Haines Junction and Skagway (Hultén 1968). Cody et al. (1998) reported this species new to the Yukon in the southeast corner and suggested that it be added to the list of rare species in the Yukon Territory. Map 173.

Cladothamnus pyrolaeflorus Bong. (*Elliottia pyroliflorus* (Bong.) S.W. Brim & P.F. Stevens), Copper Flower — ST. ELIAS MOUNTAINS: heather/mesic forb alpine tundra, Floral Pass, 549 m, 59°57.91′ N 139°57.76′ W, *M. Cook 87-71*, 21 August 1987.

This specimen connects the range of this North American Pacific Coastal species 322 km to the west near Cordova (*B. J. Neiland 1343*, 2 July 1965 (ALA)) with stations 249 km to the east near Haines in the Mt. Fairweather Quad (Lituya Bay, 58°40.0′ N 137°36.0′ W, *S. Doman 85-46*, 16 June 1985 (ALA)). Map 174.

Phyllodoce glanduliflora (Hook.) Cov. (*P. aleutica* (Spreng.) Heller ssp. *glanduliflora* (Hook.) Hult.), Aleutian Mountain Heather — CHUGACH MOUNTAINS: mountain heath tundra, Falls Creek, 1097 m, 61°9.2′ N 144°22.31′ W, *M. Duffy 91115*, 12 August 1991; sandy dry soil in depression surrounded by *Empetrum nigrum-Salix arctica* heath, Juniper Island, 1346 m, 60°36.17′ N 142°14.96′ W, *M. Cook 94232*, 10 July 1994; co-dominant in mesic heath, 1291 m, 60°36.24′ N 142°21.69′ W, *C. Roland 94-217*, 12 July 1994. ST. ELIAS MOUNTAINS: dwarf scrub/mixed forb herbaceous alpine tundra, Guyot Glacier, 579 m, 60°5.83′ N 141°27.3′ W, *K. Beck s.n.*, 10 August 1987; alpine tundra heath, Samovar Hills, 549 m, 60°8.11′ N 140°39.55′ W, *M. Cook 87-154*, 23 August 1987. WRANGELL MOUNTAINS: dominant on NE-facing slope, Mt. Drum, 1433 m, 62°8.83′ N 144°30.18′ W, *M. Cook 94056*, 11 June 1994.

This species is North American with a cordilleran distribution. The localities cited above extend its range 161 km northeast into the Wrangell Mountains and 232 km east into the Chugach Mountains from a station near Valdez (Hultén 1968). The specimens from the southern St. Elias Mountains connect the range 113 km to the east at Yakutat (Hultén 1968). Map 175.

PRIMULACEAE

Douglasia alaskana (Coville & Standley ex Hultén) S. Kelso (*Androsace alaskana* Cov. & Standl.), Alaskan Douglasia — CHUGACH MOUNTAINS: few on old mining road, Five Mile Creek, 1463 m, 61°32.58′ N 143°58′ W, *M. Cook 93463*, 27 August 1993; few on talus slope and *Dryas* tundra, Hundell Creek, 1585 m, 61°36.75′ N 144°42.2′ W, *M. Cook 93467*, 28 August 1993. WRANGELL MOUNTAINS: few along ridge at head of Elliot Creek, 1926 m, 61°38.99′ N 144°3.51′ W, *M. Cook 96468*, 16 July 1996.

This primrose is an Alaska-Yukon endemic with a Pacific Coastal distribution that is considered rare in Alaska (G2G3 S2S) and in the Yukon (Douglas et al. 1981). The collections cited above extend its range 203 km east into the Chugach and Wrangell Mountains from collections in the Anchorage Quad (Lower Snowhawk, 61°11.75′ N 149°33.25′ W, *M. Duffy 795*, 19 July 1994 (ALA)) and connect the range 275 km to the east in the Yukon Territory (Cody 1996). Map 176.

Douglasia arctica Hook., Mackenzie River Dwarf Primrose — ST. ELIAS MOUNTAINS: rare in rocky sites on steep, N-facing slopes, Mt. Natazhat, 1716 m, 61°35.38′ N 141°1.83′ W, *C. Roland 95-066*, 19 June 1995.

This primrose is an Alaska-Yukon endemic with an arctic-alpine distribution and is rare in Alaska (G3 S2S3). The collection cited above extends its range 297 km south into the St. Elias Mountains from a station near Chicken (Hultén 1968) and 296 km east from a station near Valdez (Hultén 1968). Map 177.

Douglasia gormanii Const., Gorman's Dwarf Primrose — MENTASTA MOUNTAINS: occasional in moist soil and rubble on NE-facing debris flow, Trail

169. Myriophyllum verticillatum

170. Cicuta maculata var. *angustifolia*

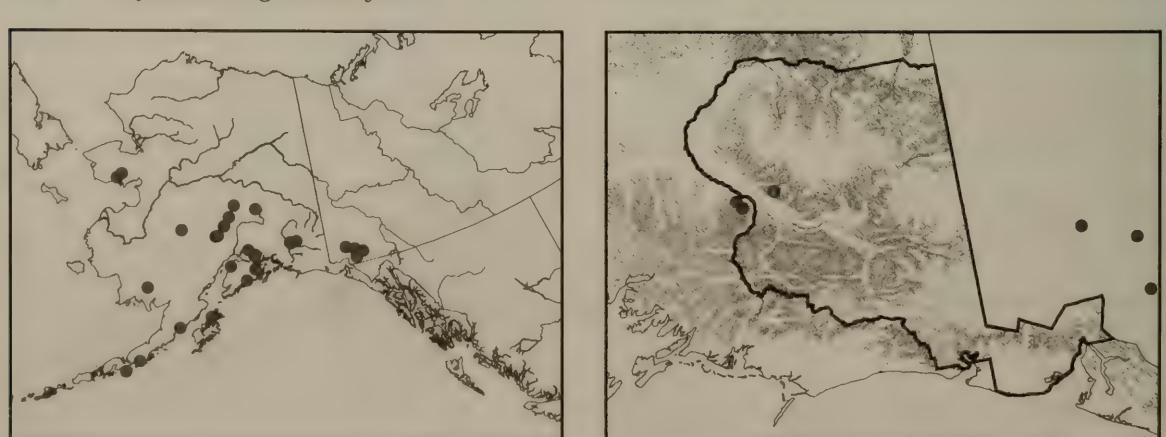
171. Ligusticum scoticum ssp. *hultenii*

172. Ozmorhiza depauperata

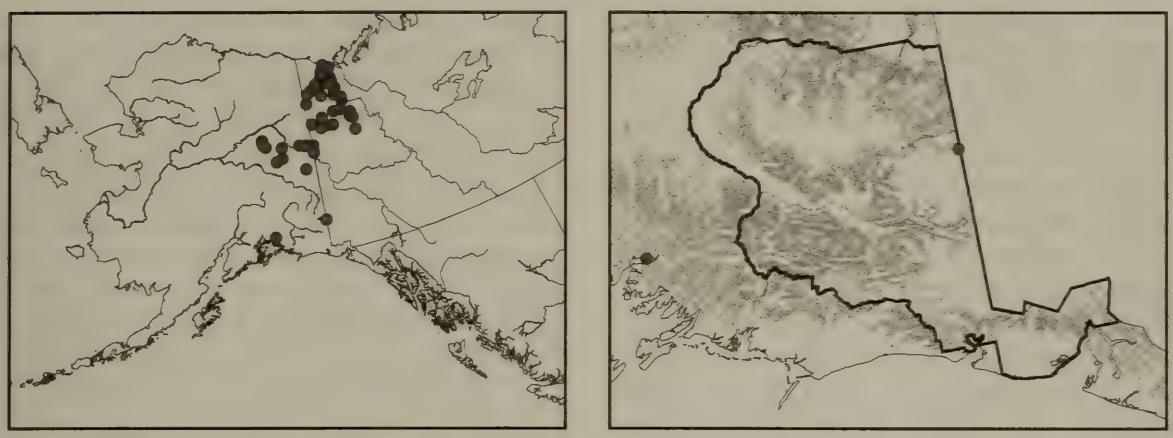
173. Cassiope mertensiana

174. Cladothamnus pyrolaeflorus

175. Phyllodoce glanduliflora



176. Douglasia alaskana



177. Douglasia arctica

178. Douglasia gormanii

179. Primula cuneifolia ssp. *saxifragifolia*

180. Primula egaliksensis

Creek, 1615 m, 62°36.05′ N 143°17.63′ W, *C. Roland 95-014B*, 6 June 1995; Upper Trail Creek, 1341 m, 62°37.09′ N 143°16.06′ W, *Potkin & Leggett 95-054*, 28 July 1995; rare near top of steep talus slope, occasional on N-facing limestone rubble slope, headwaters of Lost Creek, 1722 m, 62°36.45′ N 143°12.03′ W, *K.A. Beck 95-222*, 4 July 1995; *M. Cook 95171*, 7 July 1995; occasional in fine gravel, ridge above Totschunda Creek, 1280 m, 62°27.63′ N 142°12.44′ W, *C. Roland 96-293*, 24 June 1996; scattered in rubble chute on NE-facing slope, Devil's Mountain, 1530 m, 62°25.62′ N 142°53.93′ W, *C. Roland 96-350*, 3 July 1996. NUTZOTIN MOUNTAINS: rare on upper slope, Carl Creek, 1920 m, 62°3.52′ N 141°36.27′ W, *M. Cook 94095*, 20 June 1994; patchy on rock outcrops on northwest side of ridge, Wiki Peak, 1433 m, 61°53.9′ N 141°9.51′ W, *M. Cook 94123*, 22 June 1994; occasional in moist tundra vegetation among cobble-sized rocks, slope 4 km east of Wiki Peak, 1585 m, 61°55.98′ N 141°8.02′ W, *C. Roland 94-118B*, 23 June 1994; occasional on SW-facing scree slope, Horsfeld Creek, 1768 m, 62°2.88′ N 141°13.18′ W, *C. Roland 94-129B*, 24 June 1994; rare on southeast trending limestone ridge, Baultoff Creek, 1707 m, 62°9.13′ N 141°14.51′ W, *M. Cook 94190*, 28 June 1994; occasional on ridge growing in *Rhacomitrium*, Klein Creek, 1747 m, 62°2.29′ N 141°19.88′ W, *M. Cook 95017*, 15 June 1995; few on ridge in rocky dwarf scrub tundra, Rock Lake, 1119 m, 61°48.7′ N 141°16.57′ W, *M. Cook 96028*, 6 June 1996; scattered mid-slope in dry sandy gravel, 1411 m, 61°54.46′ N 141°10.68′ W, *M. Cook 96060*, 6 June 1996; common but scattered on gravel slope, Wiki Basin, 1411 m, 61°54.46′ N 141°10.68′ W, *C. Roland 96-067*, 6 June 1996; rare on well vegetated SE-facing alpine colluvium, Horsfeld Creek valley, 1128 m, 62°2′ N 141°11′ W, *Parker & Gracz 6915*, 13 August 1996; bluff east of lodge, Ptarmigan Lake, 1079 m, 61°53′ N 141°8.8′ W, *Duffy & Barnes 96-259*, 8 August 1996; scattered on NW-SE trending ridge amongst *Dryas* stripes, pass between Cabin and Wiki Creeks, 1585 m, 61°53.64′ N 141°11.4′ W, *M. Cook 3172*, 14 June 1998 (ALA); steep S-facing rhyolite scree knob, W side of Wiki Creek, 1524 m, 61°54.77′ N 141°11.05′ W, *M. Cook 3181*, 15 July 1998 (ALA); scattered in gravel patches amongst *Dryas* stringers, Ophir Creek, 1463 m, 61°55.7′ N 141°31.07′ W, *M. Cook 3191*, 16 July 1998 (ALA); scattered in sparsely vegetated basalt scree, ridge S of Sonja Creek, 1494 m, 61°57.14′ N 141°21.43′ W, *M. Cook 3194*, 16 July 1998 (ALA). WRANGELL MOUNTAINS: alpine tundra, Nabesna Glacier, 1768 m, 61°56.6′ N 143° W, *M. Duffy 92115*, 26 June 1992; N-facing scree slope, ridge between Lime Creek and Solo Flats, 1707 m, 61°50.85′ N 141°47.12′ W, *M. Cook 92110*, 7 July 1992; occasional on steep gravel slope, northeast slope of Mt. Drum, 1433 m, 62°8.83′ N 144°30.18′ W, *C. Roland 94-055*, 11 June 1994; occasional on slope of exposed, stony alluvium, Mt. Sanford cinder cone, 1722 m, 62°23.4′ N 144°15.9′ W, *C. Roland 94-002*, 6 June 1994; rare on steep W-facing gravel slopes, Cone Ridge, 2073 m, 62°8.21′ N 143°18.47′ W, *C. Roland 94-318B*, 27 July 1994; sparsely vegetated disturbed S-facing rubble, Chetaslina Plateau, 1615 m, 61°56.51′ N 144°25.93′ W, *C. Roland 94-351*, 17 August 1994; occasional in stony, frost boiled polygon tundra, Jaegar Mesa, 1893 m, 62°15.9′ N 143°1.24′ W, *C. Roland 95-115*, 1 July 1995; occasional in crevices of basalt rock ledges on ridge, Black Mountain, 1481 m, 62°20.85′ N 143°44.9′ W, *M. Cook 95153*, 7 July 1995; southwest slope of Mt. Drum, between Nadina Glacier and Klawasi River, occasional in stony areas in sparse tundra, 1615 m, 62°4.61′ N 144°46.39′ W, *C. Roland 96-328*, 2 July 1996.

This species, an Alaska-Yukon endemic with a cordilleran distribution, is rare in Alaska (G3 S3). It had been collected at four localities in the Wrangell-St. Elias Mountains: Guerin Glacier (61°37.42′N 141°4.38′W, *D. F. Murray 2046*, 3 August 1968 (ALA); Sheep Glacier (61°42.48′N 141°38.59′W, *D. F. Murray 2278*, 17 August 1968 (ALA)); Russell Glacier (61°41.93′N 141°45.36′W, *D. F. Murray 2169*, 11 August 1968 (ALA)) and Chitistone Pass (61°37′ N 142°3′ W, *R. Scott 1574, 1868*, 1915 (MICH) (Scott 1968) and *D. F. Murray 722* (CAN) (Murray 1968)). The new collections cited above extend its range 151 km into the northern and western Wrangells, 128 km northwest into the Mentasta Mountains and 90 km north into the Nutzotin Mountains. Map 178.

Primula cuneifolia Ledeb. ssp. *saxifragifolia* (Lehm.) Sm. & Forrest, Pixie-Eyes — CHUGACH MOUNTAINS: lush meadow on the margin of a seep in E-facing tundra, Juniper Island, 1346 m, 60°36.17′ N 142°14.96′ W, *C. Roland 94-194*, 10 July 1994; scattered adjacent to creek in dwarf willow-crowberry heath, plateau between Grant Creek, Tebay River and Hanagita River, 1250 m, 61°17.65′ N 143°56.34′ W, *M. Cook 96355*, 7 July 1996; several plants along the edge of a small stream, Upper Golconda Creek, 1280 m, 61°3′ N 143°24.45′ W, *L. A. & E.G. Viereck 11054*, 7 July 1996. GULF OF ALASKA: ericaceous dwarf scrub alpine tundra, tall forb herbaceous, 3.5 km NW of Hanna Lake, Robinson Mts., 610 m, 60°9.95′ N 143°6.8′ W, *M. Duffy 9256*, 13 June 1992; ericaceous dwarf scrub alpine tundra & scree slope, nunatak between peaks 2710 and 2425, Robinson Mountains, 646 m, 60°9.9′ N 143°10′ W, *M. Cook 9210*, 13 June 1992. WRANGELL MOUNTAINS: scattered in mesic *Dryas* tundra lining an intermittent stream channel on gentle SE-facing slope, Upper Dadina River, 1344 m, 62°3.95′ N 144°25.18′ W, *C. Roland 96-312*, 1 July 1996; scattered throughout basin in moss and organic soil of ericaceous tundra, upper Dadina River, 1344 m, 62°3.95′ N 144°25.18′ W, *M. Cook 96268*, 7 July 1996.

This amphiberingian species has a north Pacific coastal distribution. The specimens cited above extend the range 135 km south into the Wrangell Mountains from a collection in the Alaska Range (Maclaren Summit, 63°05.0′ N 146°23.0′ W, *D. Rhode 81/P6-85*, 20 June 1981 (ALA)), 200 km east into the Granite Range from collections at Thompson Pass (61°7.81′N 145°42.11′W, *J.P. Anderson 1910*, July 1935 (Hultén 1947)) and connect the distribution 368 km to the southeast near Haines (Hultén 1968). This species may have been collected by the Alaska Boundary Survey in 1912 at high elevations in the Wrangell Mountains. This collection was described as "Wrangell at high altitudes" by Hultén (1947) but mapped within the Eastern Pacific Coastal district. However, there are no records that the Alaska Boundary Survey visited Wrangell Island and they did travel through Skolai Pass in 1912 (Green 1982; personal communication with Geoff Bleakley, National Park Service historian, 10 October, 2000). Map 179.

Primula egaliksensis Wormsk., Greenland Primrose — MENTASTA MOUNTAINS: along stream, Soda Lake, 1494 m, 62°31.2′ N 142°54.03′ W, *Moran & Roland s.n.*, 5 July 1995; rare in *Dryas* tundra on limestone, Soda Lake, 1173 m, 62°32.36′ N 142°53.98′ W, *C. Roland 94-255B*, 22 July 1994. WRANGELL MOUNTAINS: lakeshore gravel, Jack Lake, 975 m, 62°31.2′ N 143°18.54′ W, *M. Cook 3021*, 20 June 1997.

This North America arctic-alpine primrose is rare in the southern part of the Yukon Territory (Cody 1996). The localities cited above extend its range 167 km to the south into the Mentasta Mountains from collections in the Alaska Range (Fielding Lake, 63°10.0′ N 145°41.0′ W, *G. Smith 2614*, 8 July 1955 (ALA)). Map 180.

GENTIANACEAE

Fauria cristi-galli (Menzies) Makino, Deer Cabbage — GULF OF ALASKA BASIN: mixed forb meadow, Independence Creek, Icy Bay, 427 m, 60°0.76′ N 141°27.1′ W, *K. Beck s.n.*, 12 August 1987; ericaceous shrub/graminoid herbaceous bog, Cape Yakataga, 50 m, 60°2.7′ N 142°8′ W, *M. Cook 9201*, 10 June 1992; tall forb herbaceous alpine tundra, Robinson Mountains, 671 m, 60°5.64′ N 142°17.17′ W, *M. Duffy 9234*, 12 June 1992.

This species is North American with a North Pacific coastal distribution. The collections cited above connect the range 262 km to the west near Valdez (Hultén 1968) with collection 167 km to the southeast near Pelican (Hultén 1968). Map 181.

Gentiana douglasiana Bong., Swamp Gentian — CHUGACH MOUNTAINS: subarctic lowland sedge moss bog meadow, Martin River Glacier, 91 m, 60°14.65′ N 144°1.15′ W, *M. Duffy 92265*, 3 September 1992.

This species is North American with a Pacific coastal distribution. The specimen cited above connects the range 99 km to the west near Cordova (Hultén 1968) with a locality 160 km to the east at Icy Bay (Hultén 1968). Map 182.

Gentiana platypetala Griseb., Broadpetal Gentian — ST. ELIAS MOUNTAINS: forb meadow, Moore Nunatak, 610 m, 60°4.67′ N 140°54.93′ W, *M. Duffy 92221*, 18 August 1992.

This gentian is an Alaskan endemic with a Pacific coastal distribution. The collection cited above connects the range 305 km to the west at Hawkins Island (Hultén 1968) with the range 103 km to the east at Yakutat (Hultén 1968). Map 183.

Gentianella tenella (Rottb.) Borner, Dane's Dwarf Gentian — WRANGELL MOUNTAINS: abundant in *Sibbaldia procumbens* dominated forb herbaceous vegetation on S/SW-facing snowbed gully, ridge between Chichokna and Chetaslina Rivers, 1615 m, 61°56.51′ N 144°25.93′ W, *C. Roland 94-348, 94-350*, 17 August 1994.

This circumpolar arctic-alpine species was known from the Wrangell Mountains (Chitistone Pass, 61°37′ N 142°3′ W, *R. Scott s.n.*, 1967 (MICH) (Scott 1968)). The new locality cited above extends the range 138 km to the west in the Wrangell Mountains. These populations connect the distribution 247 km to the west in the Anchorage Quad (Eklutna Valley, 61°24.0′ N 149°04.0′ W, *L. Marvin 1800*, 13 August 1984 (ALA)) with the distribution in the Yukon Territory 217 km to the east (Cody 1996). Map 184.

Swertia perennis L., Star Gentian — CHUGACH MOUNTAINS: patchy in mesic *Aulocomnium palustre*, under birch scrub, Sangaine Creek, 732 m, 61°13.13′ N 143°56.26′ W, *M. Cook 96392*, 7 July 1996. GULF OF ALASKA: Malaspina Forelands, 61 m, *K.A. Beck s.n.*, August 1987.

This species is incompletely circumpolar and has a boreal-montane distribution. It was known previously in the vicinity of the Park at Yakutat (*Stair & Pennell s.n.*, 13 July 1945 (PH) (Stair and Pennell 1946; Hultén 1941-1950)); the 141st meridian north of Mt. St. Elias (*D.W. Eaton 11*, (US) (Hultén 1941-1950)) and Indian Creek (*W.L. Poto 151*, 16 August 1902 (US) (Poto 1902*, Hultén 1941-1950)). The new collection cited above extends its range 111 km northeast into the Chugach Mountains from collections near Cordova (Hultén 1968) and connects the range approximately 162 km to the southeast at Yakutat. Map 185.

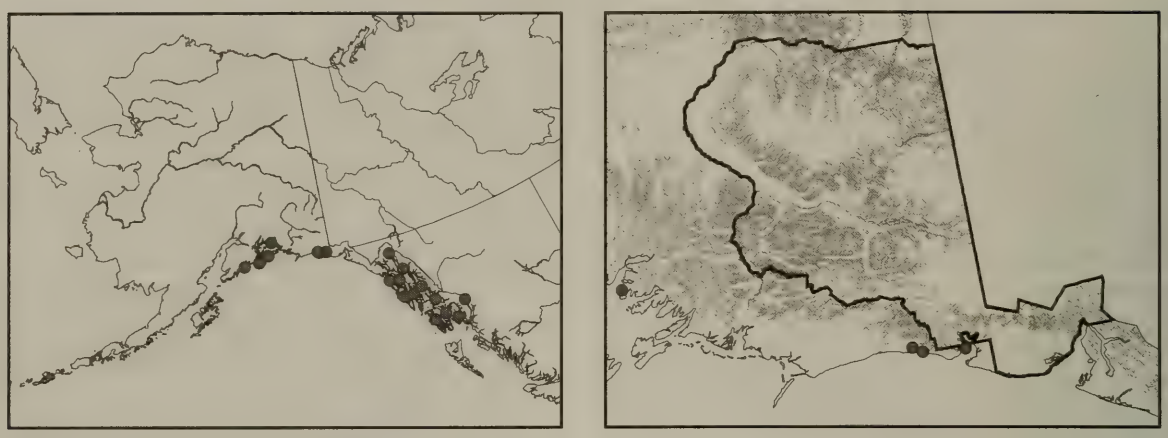
POLEMONIACEAE

Collomia linearis Nutt., Narrowleaf Mountain-trumpet — WRANGELL MOUNTAINS: gravel bar, McCarthy Creek, 61°24.51′ N 142°50.27′ W, *K.A. Beck s.n.*, 6 August 1988.

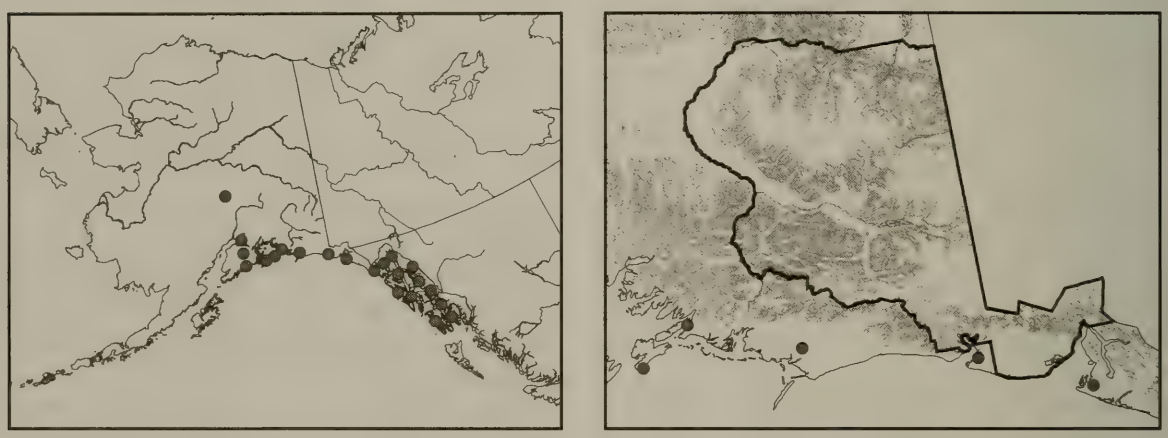
This species is native to western North America but introduced north to the District of Mackenzie, Yukon Territory, Alaska and eastward (Cody 1996). It is known from a few widely disjunct localities in Alaska. The specimen cited above is 394 km south of a collection at Eagle Bluff (64°47.0′ N 141°12.0′ W, *M. Moldenhauer Y234*, 13 July 1982 (ALA)), 379 km east of a collection near Anchorage (Hultén 1968) and 953 km northwest of a collection in the Ketchikan Quad (Hyder, 55°55.0′ N 130°00.0′ W, *J.P. Anderson 5430*, 28 June 1939 (ALA)). Map 186.

Phlox hoodii Richards., Spiny Phlox — MENTASTA MOUNTAINS: locally abundant in silty soil on steep, S-facing slopes, Devil's Mountain, 942 m, 62°24.95′ N 142°54.86′ W, *C. Roland 96-235*, *M. Cook 96239*, 22 June 1996.

This North America prairie species is disjunct from the temperate zone in Alaska and southwestern and central

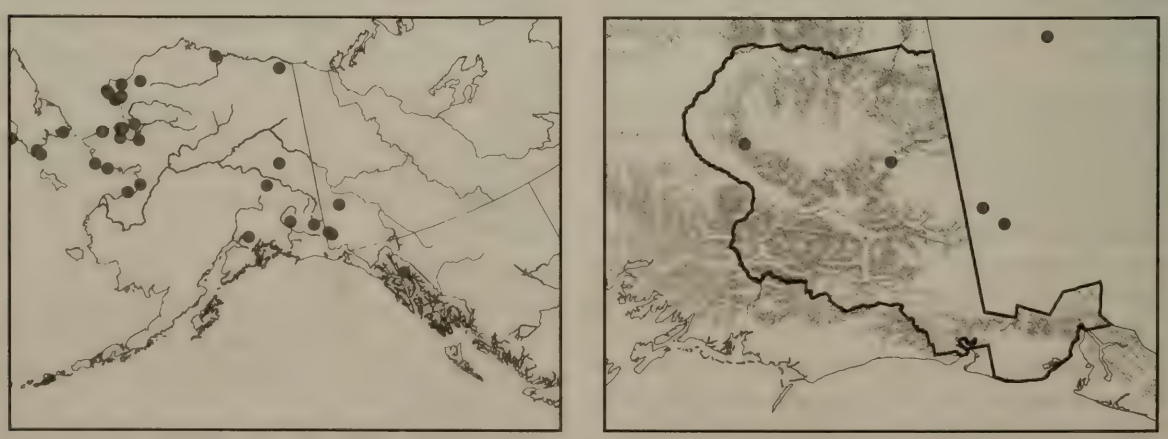


181. Fauria crista-galli

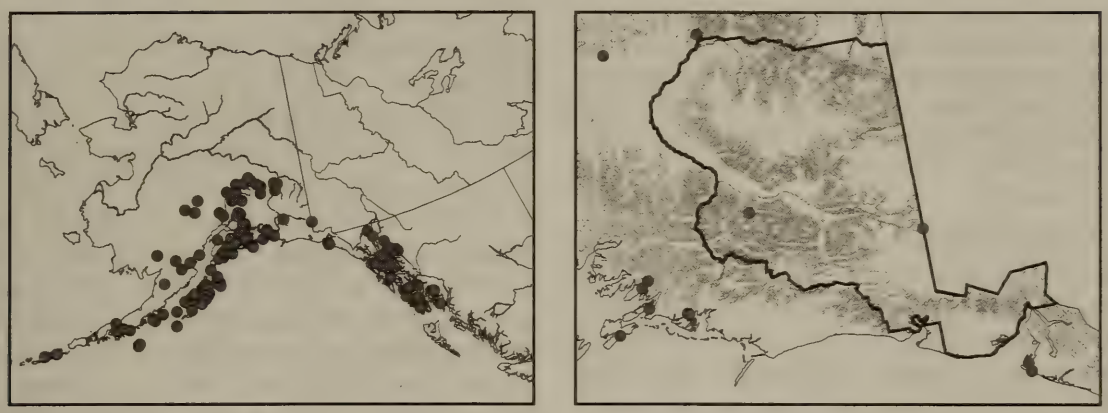


182. Gentiana douglasiana

183. Gentiana platypetala

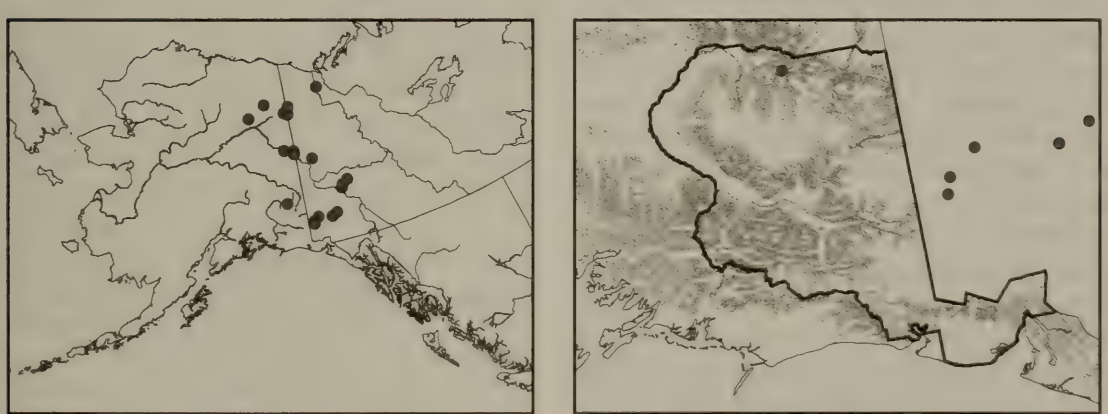


184. Gentianella tenella



185. Swertia perennis

186. Collomia linearis



187. Phlox hoodii

188. Phlox richardsonii

Yukon Territory (Cody 1996). It is considered rare in Alaska (G5 S1S2). The collection cited above from the Mentasta Mountains extends its range 290 km south from collections at Eagle Bluff (64°48.0′ N 141°12.0′ W, *Battten & Dawe 78-253*, 14 July 1978 (ALA)) and connects the distribution 194 km to the east in the Yukon Territory (Cody 1996). Map 187.

Phlox richardsonii Hook. (*Phlox sibirica* L. ssp. *richardsonii* (Hook.) Hult.), Siberian Phlox — MENTASTA MOUNTAINS: localized on S-facing greenstone outcrop, above Soda Creek, 1173 m, 62°32.36′ N 142°53.98′ W, *C. Roland 94-260*, 22 July 1994; occasional in rock crevices, SE-facing slope, Devil's Mountain, 1530 m, 62°25.62′ N 142°53.93′ W, *C. Roland 96-355*, 3 July 1996. NUTZOTIN MOUNTAINS: S-facing scree, 2 km W of Ptarmigan Creek, 1707 m, 61°55.65′ N 141°6.5′ W, *M. Duffy 92179*, 7 July 1992; S-facing scree slope, 2.4 km W of Ptarmigan Creek, 1494 m, 61°55.65′ N 141°6.5′ W, *M. Cook 92478*, 9 July 1992; locally abundant in gravel on SW-facing slope, Upper Wiki Creek, 1433 m, 61°53.9′ N 141°9.51′ W, *C. Roland 94-116A*, 22 June 1994; S-facing talus slope, ridge 1.6 km E of Rocker & Ptarmigan Creek confluence, 1433 m, 61°55.22′ N 141°2.75′ W, *Cook & Roland 94143*, 23 June 1994; locally common in rock crevices, Klein Creek, 1747 m, 62°2.29′ N 141°19.88′ W, *C. Roland 95-031*, 15 June 1995; scattered in orange rhyolite, volcanic plateau between Bryan and Willow Creeks, 1829 m, 61°58.97′ N 141°50.03′ W, *M. Cook 95051*, 18 June 1995; scattered in gravel on S-facing slopes, Rock Lake, 1119 m, 61°48.7′ N 141°16.57′ W, *M. Cook 96040*, *C. Roland 96-052*, 6 June 1996; common in barren, sand and gravel, Wiki Creek, 1411 m, 61°54.46′ N 141°10.68′ W, *C. Roland 96-068*, 6 June 1996; scattered in basalt scree, Sonja Creek, 1494 m, 61°57.29′ N 141°21.29′ W, *M. Cook 3192*, 16 July 1998 (ALA). WRANGELL MOUNTAINS: N-facing scree slope, Lime Creek, 1707 m, 61°47.2′ N 141°49.06′ W, *M. Cook 92108*, 9 July 1992; *Dryas* sedge tundra, NW slope of Mt. Sanford, 1295 m, 62°21.17′ N 144°24.52′ W, *M. Cook 93119*, 9 June 1993; S-facing volcanic slope, Capital Mountain, 1052 m, 62°31.61′ N 144°12.38′ W, *C. Roland 94-015*, 7 June 1994; scattered on S-facing slope, Mt. Sanford, 1615 m, 62°13.59′ N 144°26.06′ W, *C. Roland 94-041*, 9 June 1994; scattered in rock outcrop crevices on bluff, Nabesna River, 1106 m, 62°15.05′ N 142°54.68′ W, *M. Cook 96195*, 6 June 1996; occasional on S-facing scree slope in moist bare sandy soil, Carl Creek, 1920 m, 62°3.52′ N 141°36.27′ W, *M. Cook 95004*, 14 June 1994.

This Alaska-Yukon endemic with an arctic-alpine distribution is rare in Alaska (G4T2T3Q S2?). It was known from two localities in Alaska, one in the Yukon Territory, the Arctic Coast of the District of Mackenzie and Banks Island (Cody 1996; Porsild 1980). The stations cited above extend its range 345 km south into the Mentasta, Nutzotin and Wrangell Mountains and connects the range in the Yukon Territory, 102 km to the southeast (Cody 1996). Map 188.

HYDROPHYLLACEAE

Phacelia mollis Macbr., Soft Phacelia — MENTASTA MOUNTAINS: disturbed roadside margin, mile 34 Nabesna Road, 884 m, 62°21.18′ N 143°6.79′ W, *K.A. Beck s.n.*, 1989; large population in rubble slope and tundra, ridge S of Soda Creek, 1173 m, 62°32.36′ N 142°53.98′ W, *C. Roland 94-256*, 22 July 1994; *Dryas*-forb tundra & limestone scree, Lost Creek, 1646 m, 62°34.58′ N 143°5.58′ W, *M. Cook 94337*, *C. Roland 94-269*, 23 July 1994; scattered in tundra, Boyden Hills, 1442 m, 62°30.97′ N 143°2.98′ W, *C. Roland 95-088*, 27 June 1995; occasional in greenstone rubble, Soda Lake, 1494 m, 62°31.2′ N 142°54.03′ W, *C. Roland 95-141*, 5 July 1995; *Dryas* tundra, headwaters of Lost Creek, 1722 m, 62°36.45′ N 143°12.03′ W, *K.A. Beck 95-223*, 7 July 1995; scattered in dry tundra, Totschunda Creek, 1280 m, 62°27.63′ N 142°12.44′ W, *C. Roland 96-271*, 24 June 1996; occasional in ericaceous tundra, Devils's Mountain, 1530 m, 62°25.62′ N 142°53.93′ W, *Cook & Shea 96278*, 7 July 1996 (ALA); scattered in *Arctostaphylos uva-ursi-Betula* scrub, Lost Creek bluff, 1097 m, 62°33.3′ N 143°9′ W, *Roland & D'Auria 97-040*, 26 June 1997; occasional in rocky tundra, Lost Creek, 1189 m, 62°35′ N 143°9.1′ W, *Roland & D'Auria 97-060*, 26 June 1997; occasional in rocky *Dryas*-heath-forb tundra, Lost Creek, 1646 m, 62°35′ N 143°9.1′ W, *Roland & D'Auria s.n.*, 26 June 1997; patchy in low scrub, ridge between Platinum and Totschunda Creeks, 1494 m, 62°27.89′ N 142°47.38′ W, *Cook & Batten 3163*, 9 July 1998 (ALA). NUTZOTIN MOUNTAINS: N-facing graminoid forb tundra, 2.4 km W of Ptarmigan Creek, 1494 m, 61°55.55′ N 141°6.72′ W, *M. Cook 92465*, 9 July 1992; N-facing graminoid forb tundra, 2.4 km W of Ptarmigan Creek, 1494 m, 61°55.55′ N 141°6.72′ W, *M. Duffy 92180*, 9 July 1992; rare on S-facing scree slope, Wiki Basin, 1433 m, 61°55.22′ N 141°2.75′ W, *M. Cook 94142*, 23 June 1994; *Dryas* tundra slopes, headwaters of Alder Creek, 1554 m, 62°28.44′ N 142°15.06′ W, *K.A. Beck 95-205*, *95212*, *M. Cook 95132*, 29 June 1995; few in bare mineral soil, Wiki Creek, 1411 m, 61°54.46′ N 141°10.68′ W, *M. Cook 96100*, *C. Roland 96-072*, 11 June 1996; bluff E of lodge, Ptarmigan Lake, 1079 m, 61°53′ N 141°8.8′ W, *Duffy & Barnes 96-253*, 10 August 1996; few in ericaceous heath, Wiki Creek, 1615 m, 61°55.11′ N 141°11.81′ W, *M. Cook 3176*, 15 July 1998 (ALA). ST. ELIAS MOUNTAINS: occasional in ash deposit, Cub Creek, 1280 m, 61°37.27′ N 141°9.75′ W, *M. Cook 94186*, 28 June 1994; scattered over ash deposit, Mt. Natazhat, 1716 m, 61°35.38′ N 141°1.83′ W, *M. Cook 95077*, 20 June 1995.

This Alaska-Yukon endemic with a cordilleran distribution is rare in Alaska (G2 S2S3) and in the Yukon Territory (Douglas et al. 1981). It has a wide ecological tolerance being found on disturbed roadside margins and within varied sub-alpine and alpine communities from mesic tundra

to steppe bluffs. The collections cited above extend its range 129 km south into the St. Elias Mountains (with intermediate stations in the Wrangell and Mentasta Mountains) from a station at Mile 1257 on the Alaska Highway (62°58.0′ N 141°38.0′ W, *M. Williams 2137*, 17 June 1968 (ALA)). Map 189.

BORAGINACEAE

Cryptantha shackletteana L.C. Higgins (*C. spiculifera* (Piper) Payson), Shacklett's Catseye — MENTASTA MOUNTAINS: scattered in red calcareous gravel on southeast to SW-facing slopes, Totschunda Creek, 1280 m, 62°27.63′ N 142°12.44′ W, *C. Roland 96-284*, *96-295*, 24 June 1996 (ALA); barren calcareous gravels slopes above Totschunda Creek, 1494 m, 62°28.04′ N 142°40.07′ W, *C. Roland 96-369*, 4 July 1996 (ALA).

This Alaska endemic is known from only three localities worldwide, is rare in Alaska (G1Q S1) and is a United States Fish and Wildlife Species of Concern. We have previously reported this notable find (Roland and Cook 1998). This species is closely related to *C. spiculifera* (Piper) Payson which is common throughout the Great Basin states (Higgins 1969, Cronquist et al. 1984). A specimen from Chuktoka, assigned to *C. spiculifera* by Tolmachev and Yurtsev (1980), has been examined and determined to be neither *C. shackletteana* or *C. spiculifera*. The collections from the Mentasta Mountains are 280 km south of the collections at Eagle and Calico Bluffs on the Yukon River. Map 190.

Hackelia deflexa (Wahl.) Opiz, Nodding Stickseed — ST. ELIAS MOUNTAINS: edge of closed tall willow scrub, Chitina River, 351 m, 61°9.48′ N 142°43.57′ W, *M. Duffy 91034*, 3 July 1991. WRANGELL MOUNTAINS: occasional in bare soil on dry hillside, Nabesna River bluff, 0.6 km S of Bond Creek, 1106 m, 62°15.05′ N 142°54.68′ W, *C. Roland 96-155*, *M. Cook 96190*, 19 June 1996.

This North American boreal montane species is known from a few widely disjunct localities in Alaska and the Yukon and may be introduced (Hultén 1986; Cody 1996). The new localities cited above are from rivers some distance from road systems or towns. These localities are 248-253 km east of a station on the Glenn Highway (Hultén 1968, Welsh 1974) and 745 km west of a station in the southern Yukon Territory (Cody 1996; Welsh 1974). Map 191.

SCROPHULARIACEAE

Castilleja chrymactis Pennell, Green Indian Paintbrush — GULF OF ALASKA: occasional in beach strand forb herbaceous vegetation, Sudden Stream, Malaspina Forelands, 30 m, 59°47.08′ N 139°58.8′ W, *M. Cook 8858*, 20 July 1988; occasional in mesic tall forb meadow, Amphitheater Knob, 10 km east of Disenchantment Bay, Malaspina Forelands, 503 m, 59°57.1′ N 139°46.4′ W, *M. Cook 87-95*, 19 August 1987.

This Alaska endemic with a Pacific Coastal distribution is of limited distribution in Alaska occurring from the Point Gustavus area northward to the Malaspina Forelands. This species is a consolidated hybrid between *C. miniata* Doug. ex Hook. and *C. unalaschensis* (Cham. & Schlecht.) Malte (personal communication with Mark Egger, 3 June, 2000). The stations cited above from the Malaspina Forelands are in the vicinity of collections from Disenchantment Bay (*F. Funston 82*, 1892 (US) (Hultén 1949)) and Yakutat Bay (*Coville & Kearney 1147*, 1899 (US) (Hultén 1949)). Map 192.

Castilleja elegans Malte, Elegant Indian Paintbrush — CHUGACH MOUNTAINS: scattered throughout ericaceous heath, plateau NW of Nerelna Creek, 1372 m, 61°26.66′ N 144°17.69′ W, *M. Cook 96297*, 7 July 1996. WRANGELL MOUNTAINS: sedge tundra, Cheshnina Plateau, 500 m, 61°50.33′ N 144°22.50′ W, *M. Protti 9105*, *M. Duffy 91086*, 21 July 1991; mesic herbaceous/dwarf scrub tundra, ridge between Chichokna and Chetasline Rivers, 1463 m, 61° 56.51′ N 144° 25.93′ W, *M. Cook 94471*, 15 August 1994; top of small ridgetop, Chokosna River, 1097 m, 61°32.46′ N 143°32.88′ W, *J. Bolivar 84-101*, 13 July 1994; *Dryas* sedge tundra, NW slope of Mt. Sanford between Sanford and Boulder Creeks, 395 m, 62°21.17′ N 144°24.52′ W, *M. Cook 93122*, 9 June 1993; scattered in *Dryas*-graminoid tundra, NW slopes of Mt. Sanford, 1387 m, 62°20.98′ N 144°28.18′ W, *M. Cook 94411*, 30 July 1994; occasional in forb herbaceous meadow, vic. Nadina Glacier, 1768 m, 62°2.85′ N 144°41′ W, *M. Cook 94422*, 30 August 1994; common in heath snowbed tundra, volcanic ridge 6 km east of Snyder Peak, 1524 m, 62°4.47′ N 144°30.51′ W, *C. Roland 96-377*, 5 July 1996; scattered in sparse, lichen-dominated heath tundra, Cheshnina Plateau, 1399 m, 61°48.04′ N 144°6.27′ W, *C. Roland 96-871, 96-877*, 5 August 1996; *Cassiope-Dryas* heath, plateau between Long Glacier and the Cheshnina River, 1399 m, 61°48.04′ N 144°6.27′ W, *M. Cook 96718*, 8 August 1996.

This is an amphiberingean species with an arctic-alpine distribution. The collections cited above extend its range 312 km south into the Chugach Mountains and 244 km south into the Wrangell Mountains from a collection in the Alaska Range (Mt. Hayes Quad: 63°40.0′ N 144°54.0′ W, *L.A. Spetzman 86*, 20 June 1957 (ALA)). There may have been two collections in the Wrangell Mountains (Jacksina River, *Schrader & Hartman 49*, 1902 (US) and Sanford River, *W.L. Poto 100*, 1902 (US) (Hultén 1948)). Hultén determined these specimens as *C. pallida* (L.) Kunth subsp. *mexiae* Pennell in the Flora of Alaska and the Yukon (1949). Hultén followed the treatments of B. Boivin (1952) and O.V. Rebristaja (1964) in his 1968 flora in which *C. elegans* is regarded as a distinct species and *C. pallida* ssp. *mexiae* is united with *C. elegans* (Hultén 1967, 1968). However, the distribution map in the 1968 flora for *C. elegans* does not include the specimens from the Wrangell Mountains or other specimens of *C. pallida* ssp. *mexiae* as cited in the Flora of Alaska and the Yukon (1949) nor do they appear to be included on the map of *C. caudata* (Pennell) Rebr. If these stations were included in the current distribution of *C. elegans*, it would extend south to Keystone Canyon on the Richardson Highway (*J.P. Anderson 1884* (S)), west to Matanuska (*J.P. Anderson*

1908 (NY)) and include a locality near Willow Creek along the Richardson Highway adjacent to the Park (*J.P. Anderson 2003* (S) (Hultén 1949)). Map 193.

Castilleja yukonis Pennell, Yukon Indian Paintbrush — WRANGELL MOUNTAINS: scattered on rocky W-facing bluff in open alder scrub, between Nabesna River and Ellis Lake, 1310 m, 62°16.22′ 142° 55.70′, *M. Cook 3026*, 21 June 1997.

This species is an Alaska-Yukon endemic with a boreal-montane distribution. The specimen cited above represents the western extent of its distribution and extends its range 90 km into the northwest Wrangell Mountains from a collection at Skolai Pass (61°37.25′N 141°58.77′W, *D. F. Murray 1025* (CAN) (Murray 1968)). The closest station to the Wrangell Mountain collections is 190 km to the east in the Yukon Territory (Cody 1996). The collections from the Wrangell Mountains are the only two known localities from Alaska. Map 194.

Euphrasia mollis (Ledeb.) Wettst., Subalpine Eyebright — ST. ELIAS MOUNTAINS: White spruce forest, Clear Stream, 61°6.31′N 141°58.88′ W, *M. Hoffman s.n.*, 11 August 1986. CHUGACH MOUNTAINS: sand, Bremner River, 1300 m, 60°54.71′ N 144°33.33′ W, *M. Duffy 91138*, 16 August 1991.

This species is amphiberingean with a North Pacific coastal distribution. The collections cited above extend its range 205 km east into the St. Elias Mountains from collections near Cordova (Alaganik Slough 60°24.16′N 145°28.45′W, *E. Helmstetter s.n.*, 8 August 1980 (ALA)) and are 186 km northwest of collections at Yakutat (Situk, 59°40.59′N 139°37.38′W, *M.C. Muller s.n.*, 17 July 1980 (ALA)). Map 195.

Penstemon gormanii Greene, Gorman's Beardtongue — WRANGELL MOUNTAINS: small population in limestone rubble at base of hill 3070′, 1.2 km SE of Whitham Lake, 936 m, 62°19.33′ N 142°53.28′ W, *C. Roland 96-177*, *M. Cook 96198*, 20 June 1996; abundant on small knob undercut by the Nabesna River downstream of Virginia lake, 759 m, 62°21.51′ N 142°52.87′ W, *C. Roland 96-215*, *M. Cook 96230*, 21 June 1996; abundant in bare soil on steep, S-facing slopes, SW end of Devil's Mountain, 942 m, 62°24.95′ N 142°54.86′ W, *C. Roland 96-227*, *M. Cook 96234*, 22 June 1996; scattered in moss on limestone ledges and in crevices, Nabesna River at Cheslina River, 677 m, 62°47.49′ N 142°10.4′ W, *M. Cook 96260*, 25 June 1996.

This is an Alaska-Yukon endemic with a boreal-montane distribution. The collections cited above extend its range 80 km south into the Wrangell Mountains from a station on the Slana-Tok Highway in the Mentasta Mountains (62°36.0′ N 144°38.0′ W, *J.P. Anderson 8692*, 23 June 1944 (ALA)). Map 196.

Synthyris borealis Pennell, Northern Kittentails — MENTASTA MOUNTAINS: Upper Trail Creek, 1341 m, 62°37.09′ N 143°16.06′ W, *Leggett & Potkin 95-045*, 26 July 1995; occasional in fine gravel on E-facing slope, Totschunda Creek, 1280 m, 62°27.63′ N 142°12.44′ W, *C. Roland 96-294*, 24 June 1996. NUTZOTIN MOUNTAINS: few in volcanic boulder field, Wiki Peak, 1411 m, 61°54.46′ N 141°10.68′ W, *M. Cook 96096*, 10 June 1996; S-facing scree, Ptarmigan Creek, 1494 m, 61°32.89′ N 141°3.28′ W, *M. Cook 92476*, 9 July 1992; talus slope, Gold Hill Peak 5745′, 1585 m, 62°6.73′ N 141°51.82′ W, *M. Cook 9084*, 24 July 1990; seral herbs on well vegetated SE-facing alpine colluvium, 1128 m, 62°2′ N 141°11′ W, *Parker & Gracz 6912*, 13 August 1996; abundant on N-facing talus slope, 1411 m, 61°54.46′ N 141°10.68′ W, *C. Roland 96-077*, 7 June 1996; moist alpine herbs on NW-facing slope, vic. Wiki Peak, 1585 m, 61°55.98′ N 141°8.02′ W, *C. Roland 94-118A*, 23 June 1994. WRANGELL MOUNTAINS: lower slopes of cinder cone, Cone Ridge, 2073 m, 62°8.21′ N 143°18.47′ W, *M. Cook 94409*, *C. Roland 94-320*, 27 July 1994; scattered in unstable basalt scree, Black Mountain, 1481 m, 62°20.85′ N 143°44.9′ W, *M. Cook 95148*, 2 July 1995.

This species is an Alaska-Yukon endemic with a cordilleran distribution. It had been collected in the St. Elias Mountains at Guerin Glacier (61°37.42′N 141°4.38′W, *D.F. Murray 2020*, 3 August 1968 (ALA)). The new collections extend its range northwest 106 km north into the Nutzotin Mountains, 150 km into the Mentata Mountains and 153 km west into the Wrangell Mountains. These localities connect its distribution 195 km to the northwest in the Alaska Range (Hultén 1968) with the distribution to the east in the Yukon Territory (Cody 1996). Map 197.

Veronica serpyllifolia L. ssp. *humifusa* (Dickson) Syme, Thyme-leaf Speedwell — ST. ELIAS MOUNTAINS: open tall willow scrub, Guyot Glacier, 60°5.43′ N 141°25.51′ W, *M. Duffy 92254*, 22 August 1992; dry forb alpine herbaceous alluvial slope, Samovar Hills, 518 m, 60°8.35′ N 140°39.6′ W, *M. Cook 87-151*, 23 August 1987.

This species is incompletely circumpolar with a widespread distribution. It had been collected in the vicinity of the Park in Disenchantment Bay (*Coville & Kearney s.n.*, June 1899 (US) (Hultén 1947)). The collections cited above connect the coastal range 313 km to the west with the collection in Disenchantment Bay 104 km to the east. Map 198.

PLANTAGINACEAE

Plantago eriopoda Torr., Saline Plantain — COPPER RIVER BASIN: sandy riverbed, Copper River, 381 m, 62°10.5′ N 145°24.57′ W, *K. Teare 1659*, 8 June 1984; alluvium near margin of lower Klawasi mud volcano, 563 m, 62°3.52′ N 145°13.29′ W, *M. Cook 91216*, 21 August 1991; mud volcano salt pan, 62°3.69′ N 145°12.49′ W, *M. Protti 9101*, 6 June 1991; meadow, Lower Klawasi River, 366 m, 62°1.8′ N 145°20.8′ W, *C. Roland 94-001*, 29 May 1994.

This North American species is disjunct from the temperate zone in the southwest Yukon and adjacent southcentral Alaska. The stations listed above are 200 km to the

southwest of a station near Northway (Hultén 1968) and represent the western extent of its distribution. Map 199.

ASTERACEAE

Agoseris glauca (Pursh) Raf., Pale Agoseris — CHUGACH MOUNTAINS: mesic forb tundra, Upper Tebay Lake, 1219 m, 61°12.18′ N 144°23.8′ W, *M. Duffy 91113*, 12 August 1991; meadow near the Bremner River, 396 m, 60°58.98′ N 144°17.1′ W, *M. Duffy 91146*, 19 August 1991.

This North American boreal-montane species is rare in Alaska (G4G5 S1) where it reaches the western extent of its range. The specimens cited above from the Chugach Mountains connect its distribution with one locality 391 km to the southwest (Seldovia Quad: 59°40.0′ N 151°09.0′ W, *E. Berg 47*, 11 August 1988 (ALA)) with collections 478 km to the southeast near Skagway (Hultén 1968). Map 200.

Antennaria media Greene, Rocky Mountain Pussytoes — CHUGACH MOUNTAINS: moss-forb herbaceous slope, alpine valley near Hanagita Peak, 1186 m, 61°4.91′ N 143°38.86′ W, *M. Cook 96415A*, 7 July 1996; occasional in *Cassiope-Luetkea* heath of alpine basin, vic. 12-mile Creek, 1271 m, 60°48.85′ N 142°33.52′ W, *M. Cook 96625*, 7 July 1996 (ALA); rare in sand deposits near shore of Rock Lake, 1119 m, 61°48.7′ N 141°16.57′ W, *C. Roland 96-056*, 7 June 1996. ST. ELIAS MOUNTAINS: occasional in tundra gravel patches, headwaters of Chitina River between Walsh and Logan Glaciers, 1951 m, 60°53.94′ N 141°6.75′ W, *C. Roland 95-166*, 12 July 1995.

This species is North American with a cordilleran distribution. It is rare in Alaska and in the Yukon (Bayer 1993). The specimens cited above are 95 km northeast of the the only other Alaskan locality at Cordova (60°58.0′ N 145°00.0′ W, *C. Parker 1865*, 12 August 1986 (ALA)) and are 82 km east of collections in the Yukon Territory (Cody 1996). Map 201.

Arnica amplexicaulis Nutt. ssp. *prima* Maguire, Streambank Leopardbane — CHUGACH MOUNTAINS: mesic forb tundra, upper Tebay Lake, 1219 m, 61°12.18′ N 144°23.8′ W, *M. Duffy 91107*, 12 August 1991. GULF OF ALASKA: closed tall scrub, glacial barren, vic. Tann Fjord, Icy Bay, 305 m, 60°7.52′ N 141°8.1′ W, *B. Haller s.n.*, 24 August 1987.

This is a North American cordilleran species considered rare in the Yukon Territory (Douglas et al. 1981). The localities cited above connect the range 115 km to the southwest near Cordova (Hultén 1968) with the range 197 km to the east in the Yukon Territory (Cody 1996) and 110 km to the southeast at Yakutat (Hultén 1968). Map 202.

Arnica latifolia Bong., Broadleaf Arnica — CHUGACH MOUNTAINS: steep, N-facing snowflush slope, Granite Creek, 579 m, 60°44′ N 142°32′ W, *Parker & Duffy 6712*, 6 August 1996; open low willow scrub, Blue Lake, 936 m, 61°17.94′ N 144°10.71′ W, *M. Cook 96364*, 7 July 1996; patchy in mesic forb meadow, 12-mile Creek, 1326 m, 60°50.21′ N 142°30.85′ W, *M. Cook 96596*, 7 July 1996; scattered in mixed forb herbaceous meadow, Granite River, 1344 m, 60°46.44′ N 142°5.12′ W, *M. Cook 96619*, 7 July 1996; *Empetrum nigrum*/mixed forb community on wind-exposed rocky area, Falls Creek, 655 m, 61°14.17′ N 144°28.24′ W, *L. A. & E. G. Viereck 11028*, 7 July 1996; scattered in subarctic lowland sedge wet meadow, Tebay Lake, 579 m, 61°11′ N 144°24′ W, *Parker & Gracz 6745*, 7 August 1996; *Betula glandulosa* thicket, Martin Creek, 1097 m, 60°56′ N 142°23′ W, *Batten & Barker 96-256*, 28 July 1996; lush graminoid-forb meadow, Spirit Mountain, 759 m, 61°20.76′ N 144°26.89′ W, *C. Roland 96-564*, 15 July 1996. WRANGELL MOUNTAINS: common in lush streamside meadow, Mill Creek, 1241 m, 61°33.33′ N 143°28.35′ W, *C. Roland 96-661*, 24 July 1996; locally abundant in lush meadow, Castle Peak, 1219 m, 61°33.64′ N 143°19.01′ W, *C. Roland 96-692, 96-701B*, 25 July 1996; clumped in mesic tall forb-graminoid herbaceous meadow, Nadina Glacier, 1768 m, 62°2.85′ N 144°41′ W, *M. Cook 94417*, 30 August 1994. ST. ELIAS MOUNTAINS: herbaceous meadow, Karr Hills, 549 m, 60°8.66′ N 141°16.44′ W, *K. Beck s.n.*, 12 August 1987.

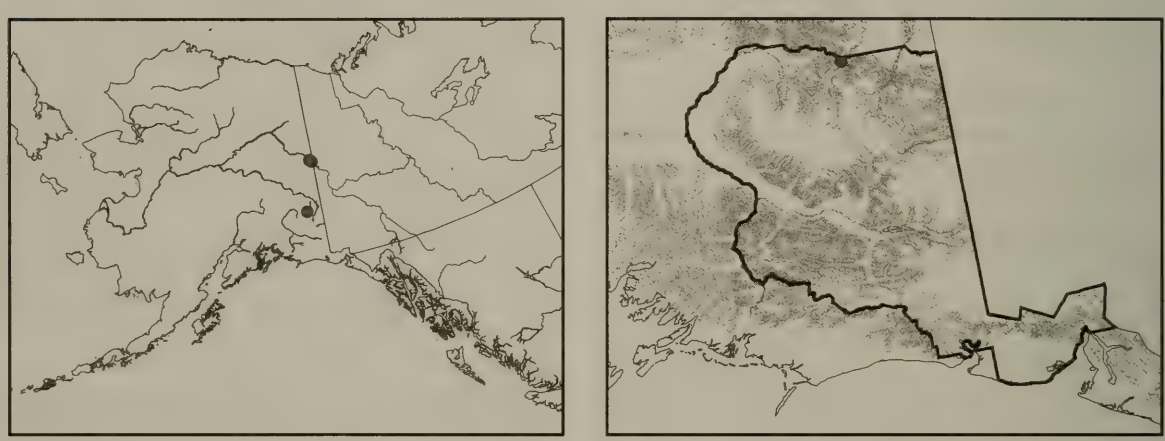
This Arnica is North American with a cordilleran distribution. The collections cited above extend its range 141 km east into the Wrangell Mountains and 244 km southeast into the Chugach Mountains from a station on the Glenn Highway near Glennallen (Hultén 1968). The southern St. Elias Mountain locality connects the range 241 km to the west near Cordova (Hultén 1968) with a station 121 km to the east at Yakutat (Hultén 1968). Map 203.

Arnica mollis Hook., Hairy Arnica — WRANGELL MOUNTAINS: forb herbaceous meadow, West Fork Mill Creek, 1241 m, 61°33.33′ N 143°28.35′ W, *C. Roland 96-659*, 24 July 1996.

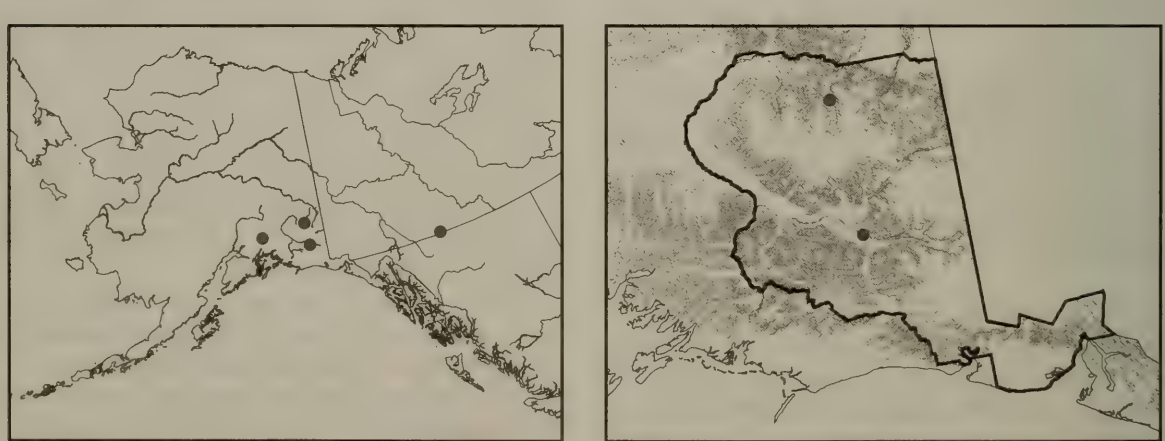
This is a North America cordilleran species which is rare in Alaska (G5 S1) and in the Yukon Terriotry (Douglas et al. 1981). The specimen cited above extends the range into the Wrangell Mountains and connects the distribution of this species 265 km to the west in the Anchorage Quad (Hatcher Pass, 61°46.0′ N 149°18.0′ W, *T. Ward 95*, 14 August 1976 (ALA)) with the distribution 445 km to the east in the Yukon Territory (Cody 1996). Map 204.

Artemisia hyperborea Rydb. (*A. furcata* auct. non Bieb.), Three-Forked Wormwood, — MENTASTA MOUNTAINS: occasional on S-facing slope in limestone gravels near ridge, Soda Lake, 1173 m, 62°32.36′ N 142°53.98′ W, *C. Roland 94-259C*, 22 July 1994; occasional on limestone outcrop between Soda and Platnium Creeks, 1494 m, 62°31.2′ N 142°54.03′ W, *C. Roland 95-139*, 5 July 1995; scattered in rocky tundra and steppe on S-facing slopes, Devil's Mountain, 942 m, 62°24.95′ N 142°54.86′ W, *C. Roland 96-241*, 22 June 1996; common on dry slopes, Totschunda Creek, 1280 m, 62°27.63′ N 142°12.44′ W, *C. Roland 96-273*, 24 June 1996;

189. Phacelia mollis



190. Cryptantha shackletteana



191. Hackelia deflexa

192. Castilleja chrymactis

193. Castilleja elegans

194. Castilleja yukonis

195. Euphrasia mollis

196. Penstemon gormanii

crevices of S-facing rock outcrop on spur ridge crest between Platinum and Totschunda Creeks, 1400 m, 62°27.83′ N 142°46.23′ W, *A.R. Batten 98-36*; south side of ridge on exposed rock outcrops, ridge between Platinum and Totschunda Creeks, 1524 m, 62°27.82′ N 142°46.27′ W, *M. Cook 3157*, 9 July 1998. NUTZOTIN MOUNTAINS: common on disturbed granitic rubble, vic. Carl and James Creek confluence, 1920 m, 62°3.52′ N 141°36.27′ W, *C. Roland 95-024*, 14 June 1994; Wiki Peak ridge, 1433 m, 61°53.9′ N 141°9.51′ W, *M. Cook 94127*, 22 June 1994; occasional in open soil, ridge 1.8 km N of Ptarmigan Lake, 1433 m, 61°53.9′ N 141°9.51′ W, *C. Roland 94-111B*, 22 June 1994; abundant on SW-facing scree slope, Horsfeld Creek, 1768 m, 62°2.88′ N 141°13.18′ W, *C. Roland 94-131B*, 24 June 1994; common on steep, S-facing rubble slope, Klein Creek, 1747 m, 62°2.29′ N 141°19.88′ W, *C. Roland 95-037*, 15 June 1995; volcanic plateau between Bryan and Willow Creeks, 1829 m, 61°58.97′ N 141°50.03′ W, *M. Cook 95053*, 18 June 1995; scattered in dry soil of subalpine steppe, Wiki Basin, 1411 m, 61°54.46′ N 141°10.68′ W, *C. Roland 96-046B*, *96-110*, *M. Cook 96062*, 11 June 1996; patchy in rocky steppe vegetation on S-facing slopes, Rock Lake, 1119 m, 61°48.7′ N 141°16.57′ W, *C. Roland 96-011, 96-011*, 4 June 1996; patchy in open low birch/willow shrub, Francis Creek, 1280 m, 61°53.29′ N 141°13.1′ W, *M. Cook 3169*, 14 June 1998; few on unstable gravel and cobble S-facing rhyolite scree slope, vic. Wiki Creek, 1524 m, 61°54.77′ N 141°11.05′ W, *M. Cook 3182*, 15 July 1998; scattered in gravel sized scree on basalt dome, Sonja Creek, 1646 m, 61°57.17′ N 141°21.92′ W, *M. Cook 3195*, 16 July 1998. WRANGELL MOUNTAINS: occasional on SW-facing talus slope, White River and Lime Creek confluence, 1646 m, 61°46.25′ N 141°50.36′ W, *M. Cook 94105A*, 21 June 1994; scattered on S-facing slope, Capitol Mountain, 1052 m, 62°31.61′ N 144°12.38′ W, *C. Roland 94-014*, 7 June 1994; locally abundant on steep, S-facing slope, Fish Creek, 1067 m, 62°16.92′ N 142°58.99′ W, *C. Roland 95-303*, 30 July 1995; common on S-facing cutbank, Mud Lake, 1001 m, 62°13.52′ N 143°45.28′ W, *C. Roland 96-894*, 10 August 1996.

This species is an Alaska-Yukon endemic with a cordilleran distribution. It was collected in the St. Elias Mountains (Sheep Glacier, 61°42.48′N 141°38.59′W, *D. F. Murray 2232*, 15 August 1968 (ALA)). The collections cited above extend the range 163 km northwest into the Wrangell Mountains, 116 km northwest into the Mentasta Mountains and 89 km northwest into the Nutzotin Mountains from the Sheep Glacier locality. These new localities connect the distribution of this species 114 km to the northwest in the Alaska Range (Gunnysack Creek, 63°32.0′ N 145°51.0′ W, *Batten et al. 78-28*, 28 June 1978 (ALA)) with the distribution 76 km to the east in the Yukon Territory (Cody 1996). Map 205.

Aster alpinus L. ssp. *vierhapperi* Onno, Alpine Aster — CHUGACH MOUNTAINS: forb herbaceous meadow, alpine basin between Twelve-mile Creek and Tana River, 1280 m, 60°49.8′ N 142°33.3′ W, *M. Hoffman s.n.*, 7 August 1986.

This North American cordilleran species is known from only eight localities in Alaska, six of these localities are quite disjunct. The collection cited above extends its range 388 km south into the Chugach Mountains from a collection in the Big Delta Quad (confluence of the Tanana & Delta Rivers, 64°09.0′ N 145°50.0′ W, *R. Howenstein s.n.*, 5 August 1983 (ALA)) and connects the Alaska range with the distribution in the Yukon Territory 157 km to the east where it is more widespread. Map 206.

Aster borealis (T. & G.) Provancher (*A. junciformis* Rydb.) — WRANGELL MOUNTAINS: occasional in *Myrica gale* dominated quaking *Drepanocladus* moss mats, 1.5 mi northwest of Billy Lake, McCarthy Road, 614 m, 61°27.99′ N 143°56.38′ W, *M. Cook 94453*, 10 August 1994.

The specimen cited above extends the range of this North American boreal-montane species 220 km west into the Wrangell Mountains from collections in the Anchorage Quad (Potter Point, 61°60.0′ N 149°55.0′ W, *Batten & Murphy 77-474*, 8 August 1977 (ALA)) and connects the distribution 189 km to the east in the Yukon Territory (Cody 1996). Map 207.

Erigeron caespitosus Nutt., Tufted Fleabane — MENTASTA MOUNTAINS: scattered on sparsely vegetated slope in sandy gravel, Devil's Mountain, 942 m, 62°24.95′ N 142°54.86′ W, *M. Cook 96238*, *C. Roland 96-228*, 22 June 1996 (ALA); occasional in dry rock crevices and rubble on SE-facing slope in midgrass herb vegetation, Devil's Mt., 1530 m, 62°25.62′ N 142°53.93′ W, *C. Roland 96-354*, *M. Cook 96282, 96283*, 3 July 1996; scattered on boulder slope, 500 m above treeline, ridge between Platinum and Totschunda Creeks, 1494 m, 62°27.82′ N 142°46.27′ W, *M. Cook 3161, 3164*, 9 July 1998. NUTZOTIN MOUNTAINS: abundant on gravel substrate in mixed forb herbaceous vegetation, Chisana airstrip, 1006 m, 62°4.16′ N 142°2.84′ W, *M. Duffy 91096*, 24 July 1991; common on SW-facing bluff, ridge 0.6 km E of Rocker & Ptarmigan Creek confluence, 1311 m, 61°54.8′ N 141°2.03′ W, *C. Roland 94-121*, 23 June 1994; common on S-facing bluff between Cub and Traver Creeks, White River, 1219 m, 61°44.3′ N 141°9.5′ W, *C. Roland 95-081*, 21 June 1995; midgrass-herbaceous S-facing bluffs, Ptarmigan Lake, 1128 m, 61°50.12′ N 141°9.15′ W, *Duffy & Barnes 96-289*, 8 August 1996. WRANGELL MOUNTAINS: locally abundant on steep, S-facing slope, Fish Creek, 1067 m, 62°16.92′ N 142°58.99′ W, *C. Roland 95-301*, 30 July 1995; common on steep SE-facing slope in sagebrush-grass vegetation, Nabesna River, 0.6 km S of Bond Creek, 1106 m, 62°15.05′ N 142°54.68′ W, *C. Roland 96-167*, 19 June 1996.

This North American species is disjunct in Alaska and the Yukon from the Rocky Mountains. It had been collected on the Nabesna River (*Schrader & Hartman 65*, 1902 (US) (Hultén 1948)) and in Chitistone Pass (61°37′ N

142°3′ W, *R. Scott s.n.*, 1967 (MICH) (Scott 1968)). The stations cited above extend its range 64 km into the Nutzotin Mountains and connect its distribution 69 km to the north along the Alaska Highway in the Tanana Valley (Hultén 1968) with the distribution 111 km to the east in the Yukon Territory (Cody 1996). Map 208.

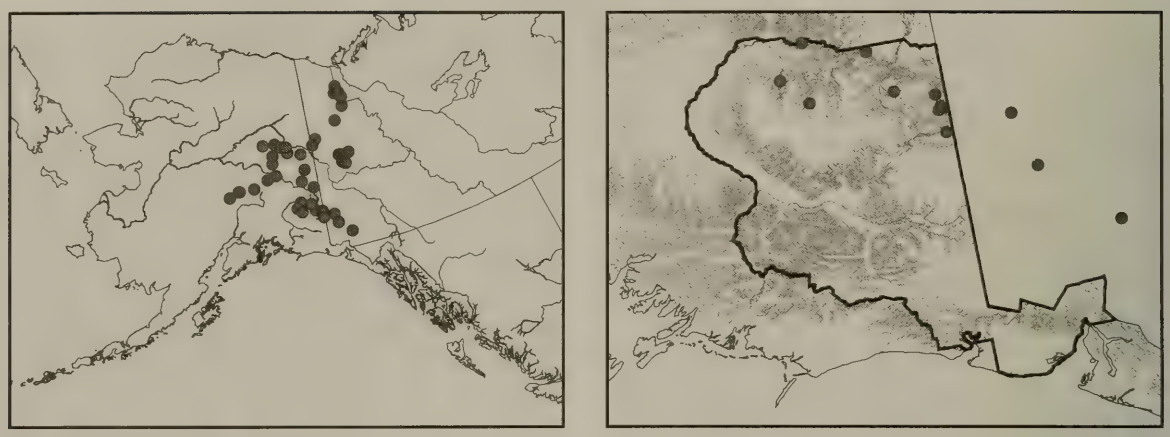
Erigeron grandiflorus Hook. ssp. *arcticus* A.E. Porsild (*E. grandiflorus* Hook. ssp. *grandiflorus*), Large-Flowered Fleabane — CHUGACH MOUNTAINS: rare in meadow, plateau above Nerelna Creek, 1372 m, 61°26.66′ N 144°17.69′ W, *Roland & D'Auria 96-420*, 8 July 1996. MENTASTA MOUNTAINS: E-facing ravine at crest on limestone ridge south of Soda Lake, 1173 m, 62°32.36′ N 142°53.98′ W, *M. Cook 94305*, 21 July 1994; scattered on SW-facing outcrop near ridge in mesic graminoid forb herbaceous vegetation, Soda Lake, 1173 m, 62°32.36′ N 142°53.98′ W, *M. Cook 94325*, *C. Roland 94-259A*, 22 July 1994; scattered on outcropping, south side of limestone ridge, Lost Creeks, 1646 m, 62°34.58′ N 143°5.58′ W, *M. Cook 94328*, 23 July 1994; scattered in sheep beds on S-facing outcrop in graminoid-forb-dwarf scrub vegetation, headwaters of Lost Creek, 1722 m, 62°36.45′ N 143°12.03′ W, *M. Cook 95182*, 7 July 1995; confined to dry forb-graminoid-*Dryas* tundra slopes above mouth of Totschunda Creek, 1280 m, 62°27.63′ N 142°12.44′ W, *C. Roland 96-274*, 24 June 1996; scattered in turfy graminoid tundra amid cobble-sized clastic talus, E-facing slope, Devil's Mountain, 1530 m, 62°25.62′ N 142°53.93′ W, *C. Roland 96-349*, 3 July 1996. NUTZOTIN MOUNTAINS: dry sandy soil on ridge, Carl Creek, 1920 m, 62°3.52′ N 141°36.27′ W, *M. Cook 95007*, 14 June 1994; steep, disturbed and xeric gravel slope, ridge 4 km north of Ptarmigan Lake, 1433 m, 61°53.9′ N 141°9.51′ W, *C. Roland 94-117A*, 22 June 1994; occasional on SW-facing slope, headwaters of Alder Creek, 1554 m, 62°28.44′ N 142°15.06′ W, *K.A. Beck 95-213*, 30 June 1995. ST. ELIAS MOUNTAINS: rare in SW-facing limestone gravels above cliffs, ridge between Dan & Copper Creeks, 1554 m, 61°21.56′ N 142°26.43′ W, *C. Roland 94-240*, 14 July 1994. WRANGELL MOUNTAINS: rare on turfy, sheep grazed site in organic rich soil of *Dryas* tundra, Crystalline Hills, 1585 m, 61°23.59′ N 143°31.85′ W, *C. Roland 95-239*, 18 July 1995; N-facing scree slope, Lime Creek, 1707 m, 61°28.41′ N 141°29.44′ W, *M. Cook 92496*, 7 July 1992; SE-facing shaley scree near ridge, Nikolai Mine, 1695 m, 61°27′ N 142°39′ W, *Batten & Barker 96-066*, 24 July 1996.

This species is an Alaska-Yukon endemic with an arctic-alpine distribution. It had been collected in the St. Elias Mountains (Guerin Glacier, 61°37.42′N 141°4.38′W, *D.F. Murray 2080*, 4 August 1969 (ALA)). The stations cited above extend its range from the St. Elias Mountains 157 km to the northwest into the Mentasta Mountains, 113 km northwest into the Nutzotin Mountains, 133 km southwest into the southern Wrangell Mountains and 170 km southwest into the Chugach Mountains. These new localities connect its distribution 185 km to the west in the Alaska Range (Hultén 1968) with the distribution 48 km to the east in the Yukon Territory (Cody 1996). Map 209.

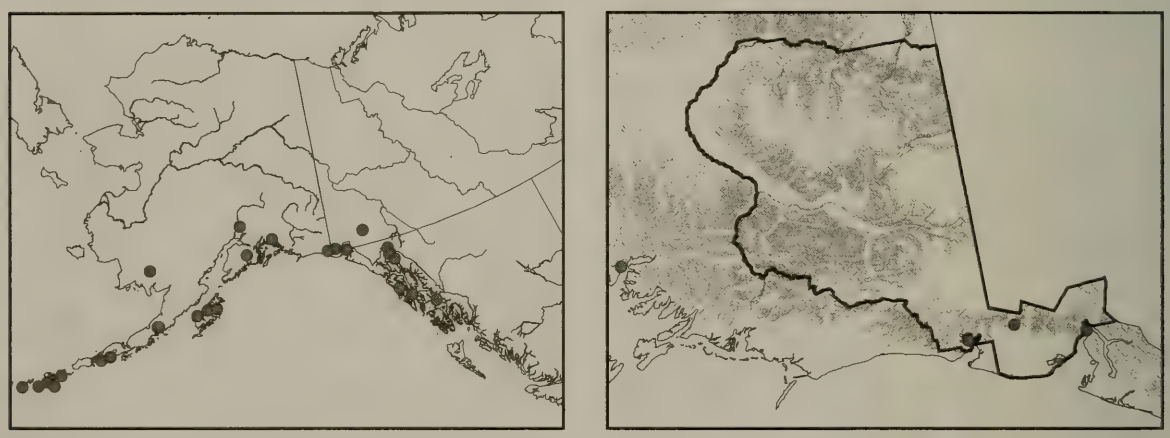
Saussurea angustifolia (Willd.) DC. ssp. *yukonensis* (Porsild) Cody (*S. viscida* Hult. var. *yukonensis* (Pors.) Hult.), Narrowleaved Saussurea — CHUGACH MOUNTAINS: *Cassiope* tundra, Towhead Mountain, 1433 m, 61°3.21′ N 142°39.8′ W, *Duffy & Barnes 96-149*, 7 August 1996; rock outcrops, Nelson Mountain, 1558 m, 61°19.37′ N 143°48.83′ W, *M. Cook 96378*, 7 July 1996. MENTASTA MOUNTAINS: Trail Creek, 1341 m, 62°37.09′ N 143°16.06′ W, *Potkin & Leggett 95-046*, 27 July 1995; limestone scree, ridge between Lost and Platinum Creeks, 1646 m, 62°34.58′ N 143°5.58′ W, *M. Cook 94340*, 23 July 1994. WRANGELL MOUNTAINS: Lakes Plateau, 1890 m, 62°4.4′ N 143°23.5′ W, *Potkin & Leggett 95-114*, 30 July 1995; rubble slope, Cone Ridge, 2073 m, 62°8.21′ N 143°18.47′ W, *M. Cook 94406*, 26 July 1994; scree slope, Lime Creek, 1707 m, 61°28.41′ N 141°29.44′ W, *M. Duffy 92209*, 11 July 1992; common in clay soil on E-facing slope, Grotto Creek, 1847 m, 61°30.56′ N 142°24.79′ W, *C. Roland 96-648*, 23 July 1996; bare gravel chert, Lime Creek, 1646 m, 61°46.25′ N 141°50.36′ W, *C. Roland 94-105*, 21 June 1994.

This species is an Alaska-Yukon endemic with an arctic-alpine distribution. It had been collected in the Wrangell-St. Elias Mountains at Bonanza Ridge (Nordell and Schmitt 1978), Sheep Glacier (*D.F. Murray 2239* (ALA) 1968), Guerin Glacier (*D.F. Murray 2089, 2027*, (ALA) 1968) and Chitistone Pass (Scott 1968). The collections cited above extend its range 134 km northwest into the Mentasta Mountains and 139 km west into the western Wrangells and connect its distribution 207 km to the northwest in the Alaska Range (Hultén 1968) with its range in the Yukon Territory (Cody 1996). Map 210.

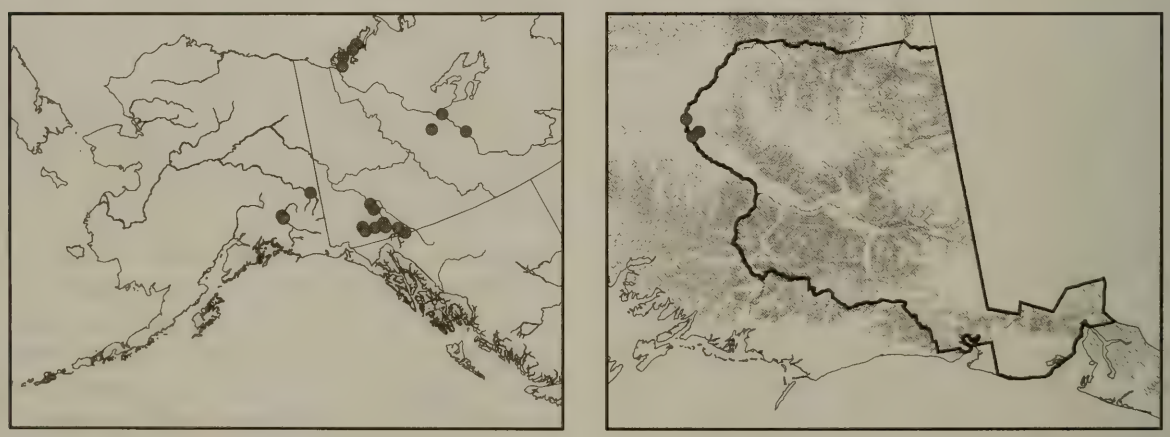
Taraxacum carneocoloratum Nels., Pink Dandelion — MENTASTA MOUNTAINS: rare on N-facing scree slope in Nikolai Greenstone and limestone units, Soda Lake, 1173 m, 62°32.36′ N 142°53.98′ W, *M. Cook 94301*, 21 July 1994; few in reddish gravel scree, SE-facing slope above Totschunda Creek, 1494 m, 62°28.28′ N 142°40.5′ W, *K. Shea 96287*, 7 July 1996; ridge above Totschunda Creek, few 5 m below ridge in sparsely vegetated orange gravel scree, 1451 m, 62°29.02′ N 142°43.94′ W, *M. Cook 96293*, 7 July 1996. NUTZOTIN MOUNTAINS: ridge 1.6 km W of Ptarmigan & Rocker Creek confluence, alpine tundra and rock slope, 1615 m, 61°54.81′ N 141°5.51′ W, *M. Duffy 92187*, 9 July 1992; ridge at headwaters of Alder Creek, occasional on S-facing boulder and rubble slopes, 1554 m, 62°28.44′ N 142°15.06′ W, *K.A. Beck 95-216*, 29 June 1995. ST. ELIAS MOUNTAINS: Mt. Chitina, rare in steep, loose scree at contact between limestone and darker metamorphic rock, 2073 m, 60°57.74′ N 141°17.33′ W, *C. Roland 95-224*, 16 July 1995. WRANGELL MOUNTAINS: Lime Creek, alpine scree slope,



197. Synthyris borealis



198. Veronica serpyllifolia ssp. *humifusa*



199. Plantago eriopoda

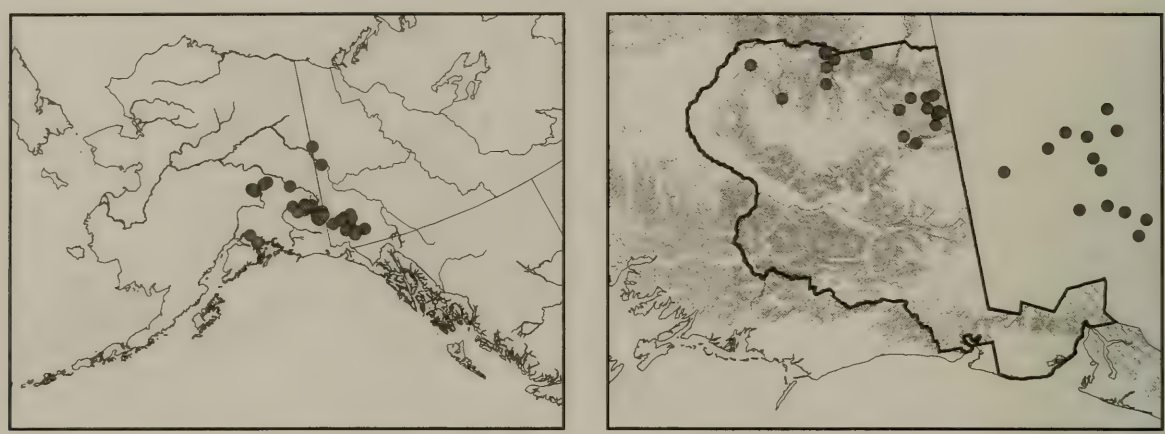
200. Agoseris glauca

201. Antennaria media

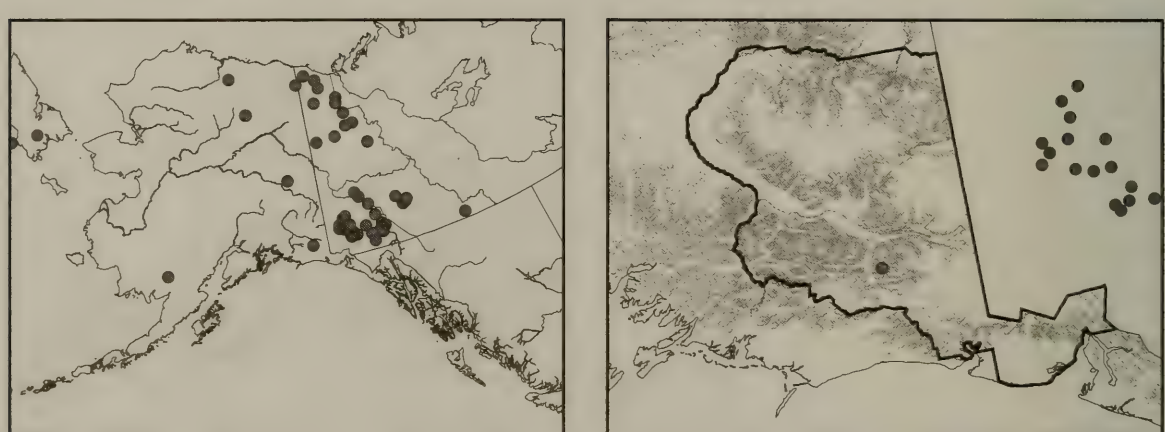
202. Arnica amplexicaulis ssp. *prima*

203. Arnica latifolia

204. Arnica mollis



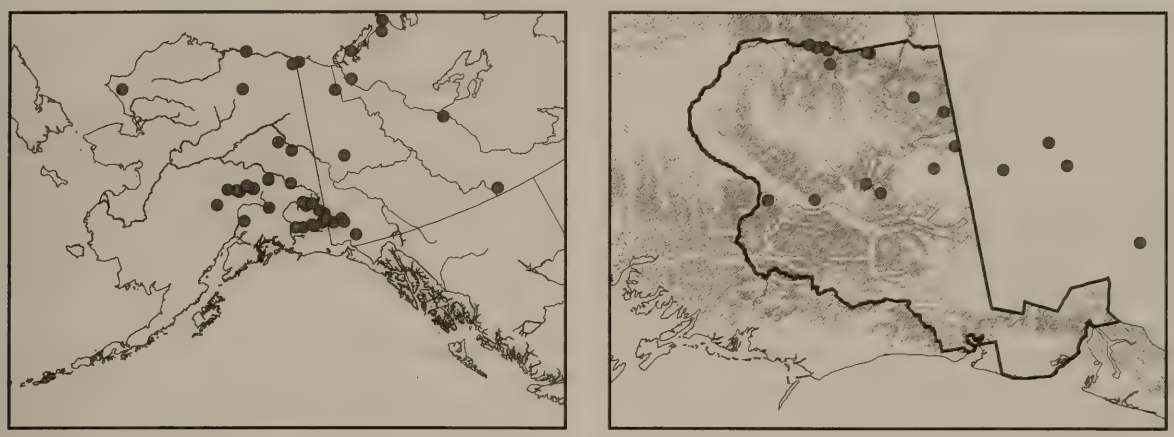
205. *Artemisia hyperborea*



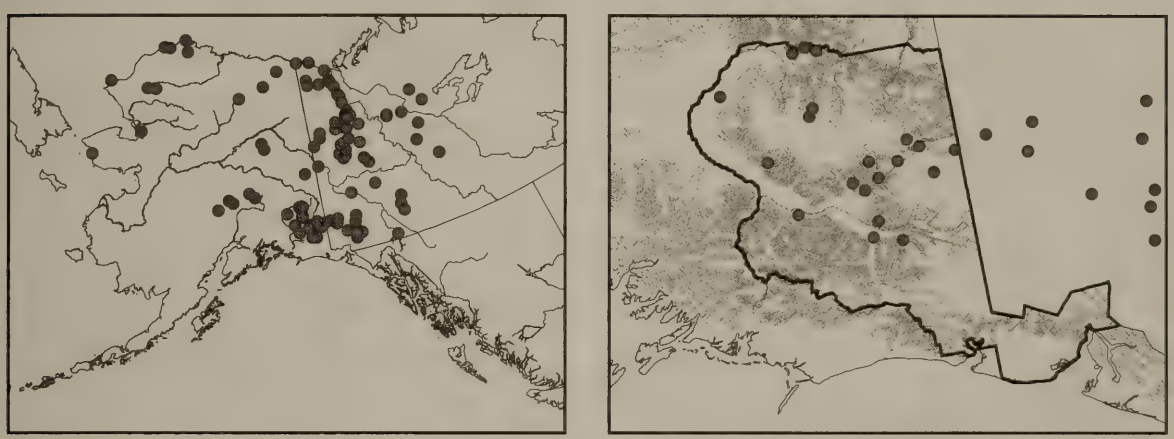
206. *Aster alpinus* ssp. *vierhapperi*

207. *Aster borealis*

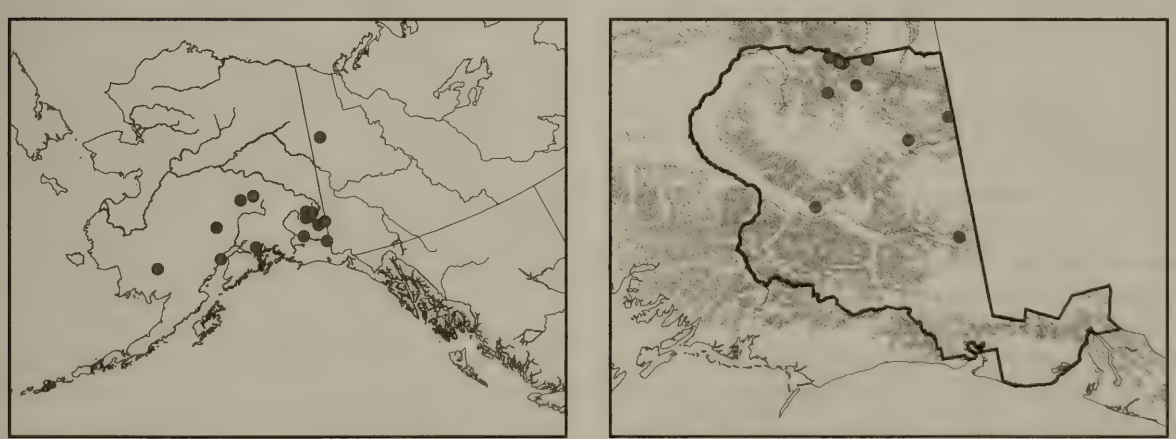
208. *Erigeron caespitosus*



209. *Erigeron grandiflorus* ssp. *arcticus*



210. *Saussurea angustifolia* ssp. *yukonensis*



211. *Taraxacum carneocoloratum*

212. *Taraxacum phymatocarpum*

1935 m, 61°47.35′ N 141°49.06′ W, *Duffy & Cook 92106*, 8 August 1992; Cooper Pass, rare in moist orange colored clay soil between gravel and thin bedded talus shale on N-facing slope, 1942 m, 62°17.16′ N 142°31.44′ W, *M. Cook 94357*, 24 July 1994; rare in rocks and gravel on ridgeline, Crystalline Hills, 1585 m, 61°23.59′ N 143°31.85′ W, *C. Roland 95-242*, 18 July 1995; mesic rubble slope, Jaegar Mesa, 1893 m, 62°15.9′ N 143°1.24′ W, *Moran & Roland 95-45*, 8 August 1995.

This Alaska-Yukon endemic with a cordilleran distribution is known from one locality in the Yukon Territory and sixteen localities in Alaska, ten of which are cited above from the Park. These collections are 273 km east of a station in the Anchorage Quad (Campbell Lake, 61°07.17′ N 149°29.75′ W, *Lichvar et al. 8082A*, 19 July 1994 (ALA)) and 409 km south of the station in the Ogilive Mountains, Yukon Territory (Murray and Lipkin 1987). Hultén (1973) indicated that this species may be the same as *T. soczavae* Tzvelev, whereas Welsh (1974) considered it to be a variant of *T. eriophorum* Rydberg (Murray and Lipkin 1987). Map 211.

Taraxacum phymatocarpum J. Vahl (*Taraxacum lyratum* (Ledb.) DC. in part), Northern Dandelion — CHUGACH MOUNTAINS: scree, West Fork Goat Creek, 1487 m, 60°59.5′ N 142°1′ W, *Batten & Barker 96-301*, 29 July 1996 (ALA).

This species is amphiberingean with an arctic-alpine distribution. The collection cited above extends the range 554 km south into the Chugach Mountains from a station in the Steese-White Moutains (Hultén 1968) and connects the range 164 km to the east in the Yukon Territory (Cody 1996). Map 212.

Acknowledgments

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Notes

Black Bear, *Ursus americanus*, Hair and Apple Trees, *Malus pumila*, in Northeast North America

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Molecular genetic techniques make it possible to use extremely small DNA samples for genetic analysis of Black Bears (*Ursus americanus*). Non-invasive sources of DNA include feces and hair. Compared to feces, hair has the advantage of being a stable source of DNA and may be taken from living or dead bears. A number of researchers have collected hair in "hair traps", where bears are induced to reach across barbed wire to get at a bait. However, we have discovered that in the Northeast bears climb wild Crab Apple trees (*Malus pumila*) in the fall for fruit and leave hairs on bark and broken twigs in the process. In this part of the United States and Canada, feral Apple trees appear to be a productive source of bear hair that has application for genetic studies.

Key Words: Black Bear, *Ursus americanus*, genetics, Wild Crab Apple tree, *Malus pumila*.

The combination of modern molecular genetics and non-invasive collection of genetic material represents one of the most exciting advances in field biology since the development of radiotelemetry in the 1960s and 1970s (Parker et al. 1998; Taberlet and Waits 1998; Woods et al. 1999). Using microsatellite techniques and DNA samples obtained from tissue, feces, or hair, geneticists are able to identify individuals, sex, members of immediate family groups, members of more distant breeding populations, as well as estimate size of effective breeding population (Taberlet et al. 1993; Paetkau and Strobeck 1994; Haig 1998; Waples 1989). A key aspect in these procedures has been the development of the polymerase chain reaction (PCR), which makes it possible to work with very small genetic samples (Taberlet et al. 1996).

Information obtained from these genetic analyses may be particularly important in field studies of animals that: (1) have large home ranges, (2) occur at low densities, or (3) are difficult to capture and mark. Large home ranges (>250 km^2) make conventional radiotelemetry difficult because animals often move beyond the range of receivers. Animals that occur at low densities may be difficult to locate or attract and are therefore problematic for capture and radiotelemetry. Capture of some large mammals, such as bears or large cats, may involve inherent risks to researchers or study animals through use of drugs or dogs.

Black Bears (*Ursus americanus*) exemplify all of the above difficulties. They occur at low densities (e.g., 1 bear per 6 km^2 in Minnesota [Rogers 1987], 1 bear per 30 km^2 in Michigan [Whitaker and Hamilton 1998]). They are shy, solitary, and almost impossible to observe in the field. Young male bears disperse long distances from their mother's home range (>100 km) (Pelton 2000), and male bears in particular have large home ranges (e.g., 318 km^2 in Massachusetts [Elowe 1984], 170 km^2 in Pennsylvania [Alt et al. 1980]). Once attracted to bait or treed by dogs, the bear must be drugged to be handled, which carries an inherent risk to the bear.

One advantage of genetic techniques is that DNA samples can be taken from a number of sources and incorporated into the same analysis. Tissue samples may be taken from animals that have been captured or freshly killed. Non-invasive sources of genetic material include feces, which contains cells sloughed off the lining of the intestinal tract (Höss et al. 1992; Kohn et al. 1995; Wasser et al. 1997). The major problem encountered when amplifying DNA from feces is inhibition of the *Taq* polymerase (Kohn et al. 1995). Although some problems, such as uneven distribution of cells shed from the intestinal lining (Kohn et al. 1995), have been solved by modifications of techniques (Wasser et al. 1997), others, such as DNA degradation, limit the utility of using feces as a source of DNA (Kohn et al. 1995). A second non-invasive source of DNA is hair (Taberlet and Bouvet 1992; Goosens et al. 1998). Basal cells at the root of a single hair have enough DNA for analysis when used in conjunction with PCR (Higuchi et al. 1988). Compared to feces, hair has the advan-

tage of being a stable source of DNA, and hair may be removed from live or dead bears (hunter-killed or road-killed).

"Hair-traps" or "hair-snares" have been used by a number of researchers to collect hair samples from bears (Woods et al. 1999). These devices involve a fragrant bait circled by barbed wire with the intent of snagging hair on a barb when a bear goes for the bait. Again, because hair is dry, the DNA sample is stable and hair traps can be checked infrequently.

Another source of hair samples that has not been reported to date is wild Crab Apple trees (*Malus pumila*). Bears climb feral Crab Apple trees in the late summer and early fall to obtain fruit (Bennett et al. 1943; Rogers et al. 1988; Willey 1980), and they leave hairs stuck under the rough bark or on twigs and broken branches. Trees that have been recently climbed by bears are easy to recognize because the bears' claws expose orange cambium, and outer branches are frequently broken. The wilted leaves on the broken branches contrast with other leaves on the tree. However, by late autumn the orange color of the cambium layer fades, and without leaves, trees that have been climbed are not easy to spot from a distance.

Second growth forests in the northeastern states and provinces have many abandoned apple orchards left from small farms that used to dot the rural landscape. Apple trees, Lilac bushes (*Syringa vulgaris*) and old cellar holes are often the only reminders of these former farms. Bear hairs on feral apple trees were not obvious and often required 15–20 min before we were able to find any hairs at all. However, the rate of return per unit effort from taking hairs from apple trees must far exceed the rate of return from hair-traps. During fall 1999 we obtained hair samples from 176 apple trees at 29 locations scattered across Vermont. These samples were collected on 21 field days. Hair samples were easiest to find during the period when bears were actively climbing trees, which lasted about four weeks. We were still able to find hairs on trees after this time, but over the next 4–6 weeks bear hairs became progressively more difficult to find as they were blown or washed off of apple trees by wind and rain.

Black Bears climb two other trees in the Northeast for fall fruit, Black Cherry (*Prunus serotina*) and American Beech (*Fagus grandifolia*) (Bennett et al. 1943; Beeman and Pelton 1980; Rogers et al. 1988; Wolfson 1992). Mature cherry and beech trees are tall and have few side branches on which to catch hairs. Black Cherries have hard rough bark on which it is difficult to see claw marks. Beech trees have smooth bark on which it is easy to see claw marks, but the bark does not have anything to catch hairs. For this reason, apple trees seem unique in being easy for researchers to climb and in having dense prickly branches and rough bark that seem "designed" to capture bear hairs.

In summary, apple trees in abandoned orchards are an excellent source of Black Bear hair that can be used for genetic analysis. Discovery of bear hairs requires careful inspection of the trees and frequent climbing to follow the path of bear tracks up the tree. If "wild" apple trees are available, obtaining hair samples in this manner is certainly more efficient than the use of hair-traps, but project objectives would dictate which method is best.

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Large Clutch Size of a Burrowing Owl, *Athene cunicularia*, Found in Saskatchewan

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During the summer of 1999, we observed a pair of Burrowing Owls (*Athene cunicularia*) lay 14 eggs in a nest near Wilcox, Saskatchewan. This represents the largest clutch size ever recorded for this species. Burrowing Owls typically lay between six and 11 eggs, and prior to our discovery the largest clutch size ever recorded was 12 eggs. Although all 14 eggs hatched, the brood was substantially reduced by cannibalism within two weeks, and in the end only 8 of the 14 chicks fledged. Marked hatching asynchrony, typical in this species, was not observed at this nest.

Key Words: Burrowing Owl, *Athene cunicularia*, clutch size, hatching asynchrony, Saskatchewan.

Burrowing Owls (*Athene cunicularia*) were listed as an endangered species in Canada in 1995 (Wellicome and Haug 1995) due to prolonged and severe declines in the population. This species inhabits open prairies, steppes, and deserts throughout North and South America, and reaches the northern limit of its range in Saskatchewan and Alberta. In Canada, Burrowing Owls do not dig their own burrows, but rather inhabit burrows originally excavated by animals such as ground squirrels (*Spermophilus* spp.), Prairie Dogs (*Cynomys ludovicianus*), and Badgers (*Taxidia taxus*).

Due to their fossorial nesting habits, reliable data on variability in Burrowing Owl clutch size is scarce. Bendire (1892) estimated that clutch sizes ranged from 6 to 11 eggs, with rare instances of 12-egg clutches (Bent 1938). Murray (1976) reported clutch size varying from 1 to 11 eggs across the species' North American range. Recently, the use of artificial nest boxes has enabled easier access to nests and thus the ability to collect more accurate data on clutch size. Over a six-year period in Saskatchewan, Wellicome (2000) reported clutch sizes in artificial nest boxes ranging between 6 and

12 eggs, with the majority of pairs laying clutches of between 8 and 10 eggs.

In the summer of 1999, while monitoring a population of Burrowing Owls on the Regina Plain, Saskatchewan, we observed a pair of owls lay a clutch of 14 eggs near Wilcox (50° 05′ N, 104° 42′W). To our knowledge, this is the largest clutch ever reported for this species. Boon (1963) reported seeing 14 young Burrowing Owls at a nest site near Elbow, SK, however, that instance was likely a result of juveniles from two or more nests congregating together after fledging (Roy 1996). Intermixing between nests is quite common when juveniles begin to disperse (Todd 2001), and Boon's observation occurred within the post-fledging dispersal period (31 August).

We observed the pair of owls for the first time at their nest burrow on 28 April 1999. We visited the nest once every two to three days as part of an ongoing productivity enhancement project (see Wellicome 2000), which involved the installation of artificial nest boxes and the provision of supplemental food to owl pairs after eggs had hatched. We installed an artificial nest box on 2 May 1999; on 5 May 1999 the first egg was laid, and the clutch was complete on 30 May 1999. The first eggs began to hatch on 18 June, and by 21 June all 14 eggs had hatched.

Burrowing Owls are known to exhibit hatching asynchrony that often results in more than a week's difference in the age of the oldest and youngest chicks in the nest (Olenick 1990; Wellicome 2000). Typically, incubation begins after the first few eggs in the clutch are laid, and the female continues to lay eggs at a rate of one every approximately 36 hours until the clutch is complete. This results in an age differential between the oldest (first-hatched) and youngest chicks in the nest, a strategy that often results in the death of the younger siblings from starvation or cannibalism when food conditions are poor. At this nest, all 14 eggs hatched within three days, resulting in a relatively small age differential within the entire brood.

Although all 14 nestlings survived the first few days, within a week three chicks had died, and only 8 of the 14 chicks survived to fledging age (41 days post-hatch). We were unable to determine the ultimate cause of death for any of the chicks, or whether it was indeed the youngest chicks that were killed. Chick remains were found inside the box (indicating cannibalism had occurred); however, it is unclear whether the nestlings were killed by their siblings and then eaten, or were eaten after dying of some other cause (i.e., starvation, trampling, etc.).

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Dispersal by a Male American Marten, *Martes americana*

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A radio-collared adult male American Marten in an unharvested population in the Black Hills of South Dakota was initially captured 1 April 1999 and relocated 32 times until found dead 7 December 1999. Over a 21 to 56-day period (5–26 May to 18 April–12 June) it travelled 74 km (straight-line distance between capture site to location at death). The two farthermost locations were 82 km apart.

Key Words: American Marten, *Martes americana*, Black Hills, dispersal, movements

Dispersal is the movement of an animal from its natal range to its first or subsequent breeding range, or where it would have reproduced had it survived (Shields 1987). American Martens (*Martes americana*) are born in spring (Mead 1994), attain adult size by autumn (Brassard and Bernard 1939), and are able to disperse at that time (Strickland 1994). Dispersal may occur, however, as late as February through the following September (Slough 1989), or possibly, not at all, under conditions of high prey densities (Powell 1994). Transient or resident Martens have dispersed ≤ 20 km from capture sites or previous home ranges (Bateman 1986; De Vos and Gunther 1952). Thompson and Colgan (1987), however, reported longer dispersal distances of three resident adult Martens during years of scarce prey. Two males, ages 3 and 4 years, were trapped 48 and 40 km, respectively, from home ranges they occupied for 2 years; and one, five-year-old, female was captured 80 km from its home range of 28 months. We describe long-distance dispersal of an adult male American Marten in an unharvested population in the Black Hills of South Dakota and Wyoming.

The Black Hills is an isolated mountain range located in western South Dakota and northeastern Wyoming. The mountains cover about 8400 km², and are surrounded by the Northern Great Plains (Fecske et al. 2002). The Black Hills has a semi-arid continental and mountain climate. Forests occur at elevations between 1200 and 2100 m. Ponderosa Pine (*Pinus ponderosa*) forest alliances comprise 84% of the Black Hills forests (Rumble and Anderson 1996); other forest alliances include White Spruce (*Picea glauca*) and Burr Oak (*Quercus macrocarpa*) (Hoffman and Alexander 1987). Average annual precipitation ranges from 45 to 66 cm (Orr 1959). Annual mean temperatures range from 5–9° C, with extremes of -40–44° C (Thilenius 1972). Forests are managed by the United States Department of Agriculture Black Hills National Forest primarily for timber production, livestock grazing, and recreation.

Historically, American Martens occurred in South Dakota (Graham and Graham 1994; Turner 1974) and were documented in the Black Hills in the late 1800s and early 1900s (Fredrickson 1993*; Turner 1974). Nonetheless, between 1930 and 1979, no Martens were harvested from the Black Hills. In 1980 and 1981, a reintroduction effort was initiated by the South Dakota Department of Game, Fish and Parks (Fredrickson 1993). Forty-two Martens were released into the northern Black Hills. Additionally, between 1990 and 1993, 83 Martens were released in the central Black Hills. In 1998, a study was initiated to estimate population size and document the current distribution of American Martens within the Black Hills of South Dakota.

A male American Marten (Marten number 325) was live-trapped (Tomahawk Live Trap Co., Tomahawk, Wisconsin) on 1 April 1999 in Black Elk Wilderness Area (Central Black Hills, 103°33′06″N, 43°51′00″W). The Marten was immobilized with ketamine hydrochloride (10.0 mg / 454 g body weight), weighed, aged, and fitted with a radio-collar (Telonics, Inc., Mesa, Arizona). At the time of capture, the animal weighed 1,020 g and was categorized as an adult (Poole et al. 1994). We conducted weekly flights from a fixed-wing aircraft to locate the animal. Mean telemetry error was 152.0 m ($n = 4$), which was determined by placing radio-collars throughout the study area and having the pilot locate the transmitters. The Marten was not relocated every week due to the limited range of the radio-transmitter, relatively large distances moved between some locations, and inclement weather. We classified the status of the Marten according to that described in Hawley and Newby (1957); Martens that occupied a home range for > 3 months were considered resident, those that occupied a home range ≥ 1 week but ≤ 3 months were considered temporary residents, and those present in an area for < 1

*See Documents Cited section

week were transients. We considered a movement greater than 3.6 km indicative of a dispersal event because it surpassed the length of the radius of the mean home-range size (10.2 km^2, Zielinski and Kucera 1995) for the species (Kernohan et al. 1994). After the Marten died, age was confirmed using the temporal muscle coalescence (Poole et al. 1994). The estimated age of the animal at the time of its death was ≥ 3 years. Puncture holes in the skull indicated that the American Marten was likely killed by a Coyote (*Canis latrans*) (S. W. Buskirk, University of Wyoming, Laramie, personal communication), and partially consumed.

American Marten number 325 was relocated 32 times between the date of capture on 1 April and the date it was located dead, on 7 December 1999. Initially, on 6, 7, and 17 April 1999, it was located approximately 9.8 km southeast of its capture location in Black Elk Wilderness Area. Then, on 7 May 1999, the animal was located about 16.2 km west of its capture location. Between 7 and 25 May, the Marten continued traveling north and west, not remaining at any one location for more than one week until it reached the northern Black Hills, between 25 May and 13 June 1999. Over a 21- to 56-day period (5 May–26 May to 18 April–12 June), it traveled 74 km (straight-line distance from the capture site to the location of death); the two farthermost locations were 82 km apart. The Marten was relocated 23 times after it was considered resident (13 September) in the northern Black Hills. The American Marten remained in the northern Black Hills until its death, sometime between 17 November and 7 December 1999.

The information obtained on Marten number 325 revealed factors that may influence the American Marten population in the Black Hills. The long distance traveled by the adult Marten could be a result of a fragmented distribution of suitable habitat (Thompson 1994; Soutiere 1979) that occurs in the Black Hills, and the fact that the population may be at carrying capacity (Fecske et al. 2002). The Black Elk Wilderness was one of the reintroduction sites and contains relatively high densities of Martens (Fecske et al. 2002). Adult Martens are known to disperse in high-density, unharvested populations (Davis 1983; Phillips et al. 1998) because of intraspecific competition for limited resources (Powell 1994; Thompson, and Colgan 1987).

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Territorial Marking by Lone Male Gray Wolves, *Canis lupus*

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We documented three separate instances in which alpha male Gray Wolves (*Canis lupus*) scent marked and remained in their original pack's territory after all the other members of the original pack were gone due to death or dispersal. They continued to scent mark until they attracted another mate to the territory and began a new pack.

Key Words: Gray Wolf, *Canis lupus*, pack, alpha, sent marking, lone, territory, Two Toes, RLUs.

Most previous literature on the behavior of solitary Gray Wolves has focused on single yearling or adult females remaining in their original pack territory to attract a new mate (Ballard et al. 1987), and dispersing offspring of alpha pairs (Mech 1973; Van Ballenberghe 1983; Messier 1985; Gese and Mech 1991) with occasional mention of "peripheral" wolves that inhabit the edges of pack territories (Mech 1970). It was often assumed that solitary male wolves do not maintain territories by scent marking, but disperse and attempt to colonize vacant habitat or join existing packs (Ballard et al. 1987). Implicit in this assumption is that alpha males left alone will not maintain and scent mark territories previously occupied and maintained by their entire pack (Rothman and Mech 1979: 753).

Three adult male wolves from three different packs were monitored from 1991–1995, in north central Wisconsin. Two of the males, M128 and M201, and several of their pack members were radio-collared and located by aerial or ground surveillance once or twice a week. Aerial telemetry was used to delineate territories (determined by > 35 winter and > 25 summer locations (Fuller and Snow 1988)) using minimum area polygon criteria (Mohr 1947). Visual observations, winter snow track surveys (Thiel 1978; Thiel and Welch 1981) and summer howling surveys (Harrington and Mech 1982) were used to determine whether wolves were alone or with other pack members. During winter tracking, raised leg urinations (RLUs) were used to determine the presence of an alpha wolf, and double RLUs (with estrus blood) were used to determine the presence of a breeding pair (Peters and Mech 1975; Rothman and Mech 1979).

M128, an adult male of the Bootjack Lake Pack, was captured and collared on 23 July 1991. Sixty-six aerial-radio locations of an adult female (F099) had been used to delineate the territory inhabited by this pack during 1987–1988. There was evidence that M128 inhabited the area with other pack members immediately prior to his capture. Two wolves responded to howling on 13 and 18 July 1991, and previous winter tracking surveys (1990–91) indicated there had been three wolves. Data obtained from 52 aerial locations, four howling surveys, three sightings and two snow tracking surveys indicated that wolf M128 remained alone in his territory from the time of capture until 3 February 1992. Two RLUs found on a winter track survey on 6 January 1992 indicated he continued to scent mark his territory without a mate or other pack members. Wolf M128 was first seen with another wolf on 3 February 1992. The next day tracks of two animals (one being M128) and double RLUs with estrus blood were found, indicating that M128 had been joined by an adult female. He was seen on 17 subsequent aerial locations with one or more wolves during 6 February 1992–12 April 1993.

Our second case of a lone wolf scent marking and maintaining a territory involved wolf M201, an adult male from the Little Rice River Pack. M201 was captured and radio collared 23 October 1991. From capture until 31 August 1993, he occupied a territory with one or more pack members, based on aerial observations, track surveys, and the presence of RLUs with estrus blood. From 1 September 1993 until 12 March 1995, M201 was alone and remained within his territory based on 71 telemetry locations. During this period, wolf M201 continued to scent mark. M201 was snow tracked a total of 5.8 km, on 24 February 1994, and 31 January 1995. We found no tracks of other wolves but RLUs were found in three different locations on these track surveys. Six aerial observations also indicated he was alone. Three RLUs, one with estrus blood, were observed on 12 March 1995 while we were following tracks of two wolves (one being M201) for 1.9 km in M201's territory. This was the first evidence of a second wolf since 1 September 1993.

Our third case involved an un-collared male wolf nicknamed Two Toes. He was missing the center two toes on one front foot, making his tracks easy to identify. Two Toes appeared to be the alpha male of the Ranger Island Pack in January 1992. Two wolves, one of which was missing two toes, was tracked a total of 4.8 km in that territory on 14 January and 31 March 1992. Evidence of three RLUs, with two containing estrus blood, indicated a breeding pair in this pack. No wolf tracks other than those of Two Toes were found on track surveys conducted on 8 December 1993, 22 January 1994, and 17 February 1994. We found six RLUs on snow banks along four different gravel roads in the Ranger Islands Pack's territory. Two of the RLUs were deposited on snow clumps located at road intersections normally scent marked by this pack. This indicated he continued to mark his territory while alone. Tracks of two wolves one of which was missing two toes, were followed 6.7 km on 1 January 1995 in the southwest corner of the Ranger Island Pack's territory. It appeared that "Two Toes" may have found a new mate after > 2 years of maintaining this territory alone.

The three males mentioned here scent marked an average of 0.4 RLUs per km on main roads while alone in their territories. This was less than when they were with mates or other pack members (0.7 RLUs per km). It seems that maintaining a territory after the death or dispersal of all other pack members is a viable option for some lone male wolves (Rothman and Mech 1979) and apparently lone female wolves (Ballerd et al. 1987). It could be assumed that when a suitable territory is established, the best strategy may be to scent mark this territory and wait for a mate, instead of venturing out in unfamiliar territory to find one.

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Estimating the Weight of Wolves, *Canis lupus*, from Chest Girth Measurements

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Regression equations relating weight with chest girth have been reported for a variety of wildlife species, but not Wolves (*Canis lupus*). We recorded the weights and chest girths of 114 Wolves taken in central and northern Minnesota between 1995 and 1997. Regression equations were developed for the estimation of Wolf weight from chest girth. A significant correlation existed between body weight and chest girth ($r^2 = 0.815$, $n = 114$, $P < 0.001$). There was no significant difference between regression equations when grouped by sex.

Key Words: Wolf, *Canis lupus*, chest girth, Minnesota.

Because weights are indicators of physical condition (Kirkpatrick 1980) they are useful in research and management of wildlife species and are often obtained from harvested Wolves (*Canis lupus*), or those captured for research purposes.

Several studies have demonstrated that weights can be accurately predicted from chest girth measurements of a variety of mammals. Payne (1976) developed an equation that would predict the weight of Black Bears (*Ursus americanus*) within about 95 percent of the true value for Newfoundland. Likewise, relationships between weight and chest girth have been established for Caribou (*Rangifer tarandus*), (McEwan and Wood 1966), White-tailed Deer (*Odocoileus virginianus*) (Urbston et al. 1976), Bison (*Bison bison*) (Kelsall et al. 1978), Mountain Goats (*Oreamnos americanus*) (Rideout and Worthen 1975), Grizzly Bears (*Ursus arctos*) (Nagy et al. 1984), Polar Bears (*Ursus maritimus*) (Kolenosky et al. 1989), Elk (*Cervus elaphus*) (Millspaugh and Brundige 1996) as well as several East African mammals (Talbot and McCulloch 1965), to name a few. No such relationship has been reported for the Wolf. This study was conducted to determine if a correlation between Wolf weight and chest girth existed.

Methods

Wolves were captured with foothold traps and neck snares during routine livestock depredation control activities by U.S. Department of Agriculture — Wildlife Services personnel. Wolves were taken in 15 counties in northern and central Minnesota from June

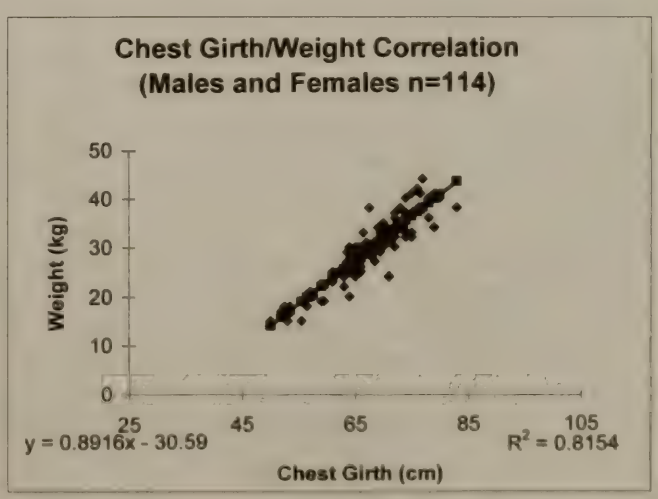

FIGURE 1. Relationship between chest girth (cm) and weight (kg) of Wolves in Minnesota, 1995–1997.

1995 through October 1997. Wolves were weighed to the nearest kilogram using a spring scale. Chest girths were taken in centimeters with a standard flexible measuring tape while the Wolves were lying on their sides; chest girth measurements were taken at the largest body circumference behind the front leg but anterior to the xyphoid process. Care was taken to make sure the tape was snug but not tight. All weights and measurements were taken post-mortem. We used Microsoft Excel 97 and Minitab 2000 version 13 to determine regression equations.

Results and Discussion

Weight and chest girth measurements were taken from 114 wolves (53 males and 61 females). A significant correlation existed between weight and chest girth for all Wolves ($r^2 = 0.815$, $P < 0.001$, $n = 114$, $y = 0.8916x\text{-}30.59$, where y = estimated whole body weight in kg and x = chest girth in cm; Figure 1). Correlations existed for both male and female Wolves as separate groups ($r^2 = 0.816$, $n = 53$, $P < 0.001$ for males, $r^2 = 0.737$, $n = 61$, $P < 0.001$ for females). We conducted a "test for parallelism" and a "test for intercepts" to determine if the slopes of the two regression lines were significantly different. No significant difference was found. Increments in girth size, whether male or female, tended to produce like increases in weight. In addition, the regression lines were not just parallel, they were virtually identical.

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Differential Use of a Wolf, *Canis lupus*, Pack Territory Edge and Core

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Based on 418 radio-locations of a Minnesota Wolf pack, Wolves were found at significantly fewer locations per area in the outer 2 km of the territory than in the core. This finding supports an hypothesis that buffer zones exist between pack territories and may explain why prey survive longer there.

Key Words: Wolf, *Canis lupus*, buffer zone, territory, White-tailed Deer, *Odocoileus virginianus*, predator, prey

Mech (1977a,b) postulated that Wolves (*Canis lupus*) may use the edges of their territories less than their centers. This proposal was based on his finding that the main prey of the wolves in his northeastern Minnesota study area, White-tailed Deer (*Odocoileus virginianus*), survived longer along Wolf pack territory edges than centers (Hoskinson and Mech 1976, Mech 1977b, Rogers et al. 1980, Nelson and Mech 1981).

Similar Wolf-deer relationships were observed in northwestern Minnesota (Fritts and Mech 1981) and on Vancouver Island, British Columbia (Hebert et al. 1982, Hatter 1984). Furthermore, theoreticians have found mathematical support for the pack territory edge as a prey refuge (Lewis and Murray 1993), and others have described similar prey-rich zones between warring Indian tribes (Hickerson 1965, 1970, Martin and Szuter 1999).

The explanation proposed for higher deer survival along Wolf pack territory edges was the possibility that Wolves spend less time along the edges because of the increased chance of encountering neighboring packs and hence intraspecific strife there. The territory edges were thus thought to be a "no man's land" or buffer zone between neighboring packs. Indeed a disproportionate number of Wolf-killed Wolves have been found in these buffer zones both in Minnesota (Mech 1994) and Alaska (Mech et al. 1998).

Although Mech (1977b) stated that the pack he studied seemed to spend less time in its territory buffer zone, only Carbyn (1983) has analyzed data to test this hypothesis. Such a test requires more location data for a single pack than are usually obtained. Here we examine a large collection of location data for one pack. We hypothesized that if Wolves tend to spend less time in their territory buffer zone, the number of Wolf locations determined by telemetry there should be significantly less per area than in the remaining core area.

Study area and Methods

We studied the Harris Lake (HL) Wolf pack that inhabited the Superior National Forest (SNF) of northeastern Minnesota. The Wolf packs in the SNF are spaced into territories, and the HL Pack territory, 19.2 km southeast of Ely (48°N, 92°W.), was surrounded by five or six other pack territories (Mech 1973). The terrain, vegetation, and land use in the territory are typical of the surrounding region and were described by Mech (1977b).

The HL pack data we used were collected by aerially radio tracking eight members of the pack of two to nine Wolves from late 1968 through early 1975 (Mech 1977b). We drew a minimum convex polygon (MCP; Mohr 1947) around a plot of the composite data from this period (Mech 1977b: Figure 5N). We divided the plot into a core area and a peripheral zone separated by a line paralleling the MCP 2 km inside (Mech 1977a). The areas of the peripheral zone and core were calculated, and the number of locations in each were tallied. Multiple points at the same location were only counted once; because most such multiple points were in and near dens in the core, any resulting bias from deleting these points would weigh against the hypothesis of fewer locations in the peripheral zone.

Results

Some 1,192 Wolf data points were obtained, and of these, 457 involved more than 1 radioed Wolf together, leaving 735 individual data points (Mech 1977b). Of these 735 points, 418 were at different locations. Of the 418 locations, 102 lay in the peripheral zone, and 316 in the core. The peripheral zone comprised 85 km^2, and the core, 138 km^2. Thus the density of locations at which radioed wolves were found was 1.2 locations/km^2 in the periphery, and 2.3 locations/km^2 in the core, a significant difference ($X^2 = 18.10$; $P < 0.001$; d.f. = 1).

Conclusion

Except for data from one of two packs studied by Carbyn (1983), these results represent the first sup-

port for the hypothesis that Wolves spend less time along the edge of their territory than in the center (Mech 1977a,b), and this finding may explain why deer survive longer along those edges, as documented above. This analysis, however, involves only a single Wolf pack territory. Additional testing with other territories for which large amounts of location data are available is necessary to further test this hypothesis further.

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Extension de l'aire de distribution de la Salamandre à quatre doigts, *Hemidactylium scutatum*, dans l'est du Québec, et notes sur l'habitat.

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Une Salamandre à quatre doigts juvénile a été trouvée au Lac du Castor, dans la municipalité de Saint-Victor-de-Tring (46°6′19″N, 70°50′55″O) le 31 juillet 2000. Cette mention constitue la première observation de l'espèce dans la région de Chaudière-Appalaches et se retrouve approximativement à 160 kilomètres au nord-est et à 145 kilomètres au sud-est des deux sites les plus près d'où l'espèce est connue. Le milieu présent à cet endroit n'est pas une tourbière à sphaigne, habitat cité le plus souvent au Québec pour cette espèce, mais plutôt un étang à castors en milieu forestier avec secteurs herbeux.

Mots-clés : Salamandre à quatre doigts, *Hemidactylium scutatum*, aire de distribution, sphaigne, habitat, Québec.

La salamandre à quatre doigts (*Hemidactylium scutatum*) est rare au Québec (Bider et Matte 1994) et figure sur la liste des espèces susceptibles d'être désignées menacées ou vulnérables (Beaulieu 1992). À cause de ses mœurs discrètes et des habitats qu'elle fréquente, tels les tourbières à sphaigne (*Sphagnum* sp.), cette salamandre est très difficile à trouver (Bonin 1998; Bider et Matte 1994). Un spécimen a été trouvé au Lac du Castor, municipalité de Saint-Victor-de-Tring (46°6′19″N, 70°50′55″O), Québec, le 31 juillet 2000. Cette mention se retrouve à approximativement 160 kilomètres au nord-est (tourbière de Marlington, comté de Stanstead, Québec, 45°2′N, 72°11′O: Sharbel 1990) et 145 kilomètres au sud-est (Saint-Maurice, comté de Champlain, Québec, 46°25′N, 72°30′O: Bider et Matte 1991) des sites les plus près où l'espèce a déjà été observée, qui se trouvent dans d'autres bassins versants éloignés.

Le spécimen trouvé au Lac du Castor est un juvénile (longueur totale : 49,5 mm; longueur museau-cloaque : 26,0 mm) et il a été découvert sous une planche de fibre de bois pressée de 70 cm × 50 cm, sous laquelle se trouvaient d'autres planches semblables. Des photographies de la salamandre et de l'habitat ont été prises par les auteurs et le spécimen a été déposé dans la amphibien et reptile Musée canadien de la nature (CMAR 35371). Le Lac du Castor n'est pas une tourbière à sphaigne, habitat souvent décrit pour cette espèce (Bonin 1998; Conant et Collins 1998; Behler et King 1996; Bider et Matte 1994; Cook 1984). Il s'agit d'un étang à castors en milieu forestier, entouré de rives d'herbacées et de Myrique baumier (*Myrica gale*) outre des secteurs à quenouilles (*Typha* sp.). La Salamandre à quatre doigts était à quatre (4) mètres du bord de l'étang, dans un secteur herbeux ouvert avec roches au sol, près de l'émissaire.

Le site a été visité dans un rayon d'environ 200 mètres afin de le décrire et de vérifier la présence de sphaigne. Le secteur de l'étang à proximité présente des buttons herbeux et des arbres morts et aucune sphaigne n'y a été vue. Quant à l'émissaire, il inonde en partie le milieu forestier adjacent constitué de forêt mixte où poussent le Sapin baumier (*Abies balsamea*), le Bouleau gris (*Betula populifolia*), le Bouleau jaune (*Betula alleghaniensis*), le Bouleau blanc (*Betula papyrifera*), l'Érable rouge (*Acer rubrum*) et le Thuya occidental (*Thuja occidentalis*). Les rives de cette zone inondée sont parfois herbeuses et quelques îlots de graminées sont aussi présents à quelques endroits. Le sol forestier en bordure de l'émissaire présente une litière de feuilles mortes assez sèches et d'aiguilles de conifères. La microtopographie est légèrement accidentée et on note la présence de quelques bûches avec mousse. Aucune sphaigne n'a été vue.

Bien que les milieux où l'on retrouve de la sphaigne soient les habitats les plus souvent cités pour l'espèce au Québec (Bonin 1998; Bider et Matte 1991; Sharbel 1990), certains auteurs y ont découvert cette salamandre en des endroits où la sphaigne était limitée à de petites parcelles dispersées (Gordon 1979; Denman 1965). La sphaigne constituerait le microhabitat optimal pour la ponte des œufs mais ne serait pas obligatoire (Petranka 1998). D'ailleurs, plusieurs observations de l'espèce faites dans des localités périphériques aux États-Unis sont typiquement dans les pentes boisées où très peu mentionnent la présence de sphaigne (Dundee 1968).

La Salamandre à quatre doigts effectue des migrations et les juvéniles quittent les sites de reproduction quelques semaines après leur métamorphose pour aller dans les forêts environnantes, où ils demeureront jusqu'à leur maturité sexuelle (Petranka 1998). Il est possible que la sphaigne soit présente en dehors du rayon de 200 m inventorié au Lac du Castor et que la salamandre, un juvénile, s'en soit éloigné. Il se pourrait également qu'à cet endroit la Salamandre à quatre doigts ponde dans d'autres

types de substrats. Outre la sphaigne, on rapporte des pontes de l'espèce dans divers types de mousses, dans la litière de feuilles mortes, sous de l'écorce au sol, dans le bois en décomposition et dans des touffes d'herbe (Petranka 1998). Bishop (1941) mentionne des observations faites dans des bois ouverts où l'herbe pousse et sous des planches et bûches près d'un étang. Ces descriptions concordent avec l'habitat retrouvé au Lac du Castor. D'autres recherches permettront peut-être de déterminer si la présence de la salamandre à quatre doigts dans ce type d'habitat constitue un fait rare au Québec ou si l'espèce s'y retrouve plus souvent que ce que l'on croit. Il serait également intéressant de chercher où pondent les Salamandres à quatre doigts dans ce secteur.

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Reproductive Characteristics of Northern Pocket Gophers, *Thomomys talpoides*, in Alberta Alfalfa Fields

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The productivity of Northern Pocket Gopher (*Thomomys talpoides*) females inhabiting eight alfalfa (*Medicago* spp.) fields in Alberta was investigated in 1994. Breeding began in late March and was virtually complete by the end of May. A total of 131 pregnant females were captured on all study sites. Females had, on average, 6.1 (standard deviation: 1.4) viable embryos. There were 295 females with placental scars. They had, on average, 5.5 (1.4) scars. In some study sites, the mean number of embryos/female differed from the mean number of placental scars. In a comparison of various Northern Pocket Gopher populations, it is recommended to use mean productivity levels obtained with the same technique, i.e., embryo or placental scar counts.

Key Words: Alberta, alfalfa, embryo, litter size, *Medicago* spp., Northern Pocket Gopher, placental scars, reproduction, *Thomomys talpoides*.

The Northern Pocket Gopher (*Thomomys talpoides*) is a fossorial rodent inhabiting hay fields of western Canada and the United States. Because of its burying and feeding activities, it is considered to seriously impact the productivity of certain crops, particularly alfalfa (*Medicago* spp.) (Proulx 1997). Alfalfa is believed to be an ideal food for this fossorial rodent because of its high nutrient and moisture content (Reid 1973). In an alfalfa field in Saskatchewan, Runnells (1988) reported an average of 6.4 embryos/litter for 17 gravid females, and 6.8 placental scars for 30 other females. Although the Northern Pocket Gopher is common in Alberta (Smith 1993), little is known about its reproduction. The objective of this study was to determine the breeding period, and average litter size of Northern Pocket Gophers inhabiting alfalfa fields in Alberta.

Methods

This study was part of a research program to investigate Northern Pocket Gopher populations, and develop an effective control strategy (see Proulx 1997). Alfalfa fields were chosen in eight rural communities in south-central Alberta: Didsbury, Caroline, Red Deer, Lacombe, Rimbey, Ponoka, Gwynne, and Camrose. The Lacombe alfalfa field was approximately 5 years old with abundant dandelion (*Taraxacum* spp.) and orchard grass (*Dactylis glomerata*). The seven other fields were 2–3 year-old fields dominated by alfalfa. Near the centre of these fields, eight study sites (one 3.6 ha and seven 8 ha each) were established (Proulx 1997). From 18 April to 27 May 1994, all pocket gophers inhabiting the study sites were kill-trapped. In Caroline and Didsbury, no trapping occurred after the spring removal; captured animals consisted only of the breeders inhabiting the study sites. In the six other fields, 20–60-m-wide traplines were established around the study sites, and maintained from 27 May to 22 September to capture animals attempting to colonize the now pocket gopher-free study sites. Therefore, in six study sites, the breeders inhabiting the study sites and those living in areas adjacent to these sites, but still living within the same fields, were captured.

Sexual maturity of females was ascertained by determining if the pubic symphysis was open (Hisaw 1924, 1925). General characteristics of uteri were noted (not bred, swollen uterus, uterus with foetus or placental scars). The number of young per litter was determined by counting the number of viable embryos or placental scars. Loeb and Schwab (1987) found in *Thomomys bottae* that the proportion of pregnancies with resorbing embryos increased as embryo size class increased. The mean crown-rump length of viable and resorbed embryos was used to classify pregnancies as early-medium term (< 21 mm), or late-term (21 mm) (Loeb and Schwab 1987).

I used an analysis of variance followed by the Tukey test to compare mean number of embryos and placental scars between populations (Zar 1984). Student *t*-tests were used to compare mean productivity levels between embryo and placental scar counts (Dixon and Massey 1969). Probability values "P" ≤ 0.05 were considered statistically significant.

Results

Breeding activities

In April, 195 (92%) of 211 females had swollen uterine walls or were pregnant. The first postpartum females were captured during the 17–23 April trapping week. The majority (65%) of females ($n = 75$) captured during the first week of May had given birth. In Didsbury and Rimbey, breeding populations were trapped by the end of April and no births were recorded. With the exception of one pregnant female

TABLE 1. Litter size in northern pocket gopher populations of Alberta alfalfa fields as determined by embryo and uterine scar counts.

Population	Non-bred females	Females with swollen uteri	Number of viable embryos				Number of resorbed embryos				Number of scars				Comparison embryos vs. scars	
			Number of females	$\bar{x}$*	*SD*	*Range*	Number of females	Number of embryos	Length (mm)† < 21	Length (mm)† > 21	*n*	$\bar{x}$*	*SD*	*Range*	*t*	P
1. Camrose	0	21	25	7.0[a]	1.8	1–9	3	4		4	68	6.4	1.4	4–10	1.692	> 0.05
2. Caroline	3	36	9	6.4[a,b]	1.0	5–8	1	1	1							
3. Gwynne	1	11	23	6.0[a,b]	1.5	4–9	4	5	2	3	57	5.2[a]	1.4	1–8	2.266	< 0.05
4. Didsbury	3	24	1	8.0												
5. Lacombe	1	12	26	5.7[b]	1.0	4–8	1	2		2	77	5.1[a]	1.1	2–8	2.458	< 0.01
6. Ponoka	0	9	24	6.4[a,b]	1.1	4–8					77	5.4[a]	1.2	2–8	3.806	< 0.005
7. Red Deer	0	8	9	5.3[b]	1.5	3–7					16	5.2[a]	1.3	2–7	0.174	> 0.005
8. Rimbey	3	22	15	5.2[b]	1.0	4–8										

*Column means with the same letter do not differ ($P > 0.05$) using Tukey test.
†Crown-rump caliper length.

captured in Lacombe in mid-June, all pregnancies were recorded before the end of May.

Productivity levels based on viable embryo counts

A total of 132 pregnant females were captured from all study sites. Only one pregnant female was captured in Didsbury, and it was not included in comparisons between populations. Females had an average of 6.1 (standard deviation: 1.4) viable embryos. However, mean productivity levels differed significantly among study sites ($F_{6,124} = 4.152$, $P < 0.005$) (Table 1). Camrose, Caroline, Ponoka and Gwynne females had the highest mean productivity. Rimbey, Red Deer and Lacombe had lower mean productivity levels that differed only from that of Camrose (Table 1).

Only 9 (7%) of 131 females had resorbed embryos, and these were all found in highly productive populations (Table 1). Twelve embryos had been resorbed, and the majority (75%) of them were > 21 mm in length (Table 1).

Productivity levels based on placental scar counts

Placental scars were found in 295 females. Mean litter size was 5.5 (± 1.4) young/female. A significant difference in mean litter sizes among study sites ($F_{4,290} = 11.747$, $P < 0.005$) was due to the markedly greater productivity of Camrose females (Table 1). Females from Ponoka, Lacombe, Gwynne and Red Deer had similar mean numbers of placental scars (Table 1).

Comparison of embryo to placental scar counts

The mean number of embryos for 131 females was significantly ($t = 4.435$, $P < 0.05$) greater than the mean number of placental scars for 295 females. There was no significant difference ($P > 0.05$) between the mean number of embryos and placental scars for Camrose and Red Deer females (Table 1). However, in females from Gwynne, Lacombe and Ponoka, the mean number of scars was significantly lower than the mean number of embryos (Table 1).

Discussion

Using a gestation period of 18–19 days (Schramm 1961; Reid 1973; Andersen 1978), capture data suggest that, in 1994, breeding began, at the earliest, near the end of March. Nearly all females captured after mid-May had given birth, and breeding activities in alfalfa fields was virtually completed before June. In Saskatchewan, Runnells (1988) reported similar findings. There, most females were pregnant in April-May, started lactating in May, and finished breeding in June. A slightly longer breeding season was reported in Colorado, from 1 March to 15 June (Hansen 1960; Reid 1973). The length of the pocket gopher breeding season likely varies among regions according to length of growing season, climate, and other extrinsic factors (Dixon 1929; Miller 1946; Desy and Druecker 1979; Runnells 1988).

Females of all populations had one litter with an average ranging from 5 to 7 young, depending on embryo or placental scar counts. However, independent of the technique used, the mean productivity level of Camrose females was consistently the highest. The higher productivity of these Camrose females may be related to differences in field characteristics (soil, moisture) and forage quality, or the age structure of adult female populations (Desy and Druecker 1979; Andersen 1980; Runnells 1988). Female Northern Pocket Gophers inhabiting Alberta alfalfa fields had mean litter sizes that were similar to those of other alfalfa field populations (Hansen 1960; Runnells 1988). These productivity levels were markedly higher than mean litter sizes of 3–5 young reported for native rangelands in Colorado (Hansen 1960; Hansen and Ward 1966).

Like Loeb and Schwab (1987), this study showed that embryo resorption occurred in female Northern Pocket Gophers, particularly in litters with large embryos. Embryo resorption could explain differences observed between mean embryo and placental scar counts. Miller (1946) suggested that embryo counts could be overestimated if some dead fetuses were in a preliminary resorption stage and recorded as normal. However, on the basis of Conaway's (1955) study with laboratory rats, Loeb and Schwab (1987) suggest that resorbed embryos could leave placental scars. Although this study was not designed to explain discrepancies between productivity levels estimated with embryo and placental scar counts, it points out that comparisons between populations should involve mean productivity levels obtained with the same technique.

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Evidence of a Second Litter in Northern Pocket Gophers, *Thomomys talpoides*

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In June 1995, we captured 12 and14 female adult Northern Pocket Gophers (*Thomomys talpoides*) in an alfalfa (*Medicago* spp.) and a pea (*Lathyrus* spp.) field, respectively, in central Alberta. Mean litter size was significantly higher in the alfalfa population (6.7 ± 1.4 young) than in the pea population (4.5 ± 1.9 young). Females from the alfalfa field produced only one litter. However, two females from the pea field bore a second litter. This is the first confirmed report of two litters produced during a single growing season by female Northern Pocket Gophers in western Canada.

Key Words: Alberta, alfalfa, embryo, *Lathyrus* spp, litter size, *Medicago* spp., Northern Pocket Gopher, pea, placental scars, reproduction, *Thomomys talpoides*.

In northern regions, the Northern Pocket Gopher (*Thomomys talpoides*) has only one breeding period (Tryon 1947; Hansen 1960), which generally lasts from March to June (Runnells 1988; Proulx 2002). Females have only one litter, which ranges in size from 3 to 5 young in native rangelands (Hansen 1960) to more than 6 in alfalfa fields (Runnells 1988; Proulx 2002).

From 12 to 18 June 1995 during an evaluation of the capture efficiency of various killing traps, we collected several Northern Pocket Gopher adult females in a pea (*Lathyrus* spp.) crop and an alfalfa (*Medicago* spp.) field near Vegreville, approximately 100 km east of Edmonton, Alberta. Reproducing females were recognized by the presence of an open pubic symphysis (Hisaw 1924, 1925). They were autopsied *in situ*, and the number of young per litter was determined by counting the number of embryos or placental scars. The mean crown-rump length of embryos was measured with a dial caliper. Comparison between mean litter sizes was done with a Student *t*-test (Dixon and Massey 1969).

We captured 12 females in the alfalfa field. They only had one litter ranging from 5 to 10 young, and averaging 6.7 (standard deviation = 1.4) young. We captured 14 females in the pea field. Ten of them had given birth, and the number of placental scars ranged from 1 to 7, and averaged 4.5 (± 1.9) young. This average was significantly smaller than that of females captured in the alfalfa field ($t = 3.310$, $P < 0.05$). The four other females from the pea field were pregnant. Two of them had 5 and 10 embryos, measuring 22 and 16 cm, respectively. Two other females bore 7 and 4 embryos, but also had 5 and 1 placental scars, respectively. Since the two females had well-developed nipples and appeared to have lactated, it is not believed that these placental scars were the result of a partial litter resorption. A decline in the number of viable embryos usually occurs in the later stages of gestation, when embryos measure ≥ 21 mm (Loeb and Schwab 1987; Proulx 2002). In this case, embryos measured 8–12 mm and were at mid-term (Loeb and Schwab 1987).

Finding a second litter in the pea field population was a surprise because Proulx (2002), after examining 426 females in highly productive alfalfa fields, reported only one litter per female. Previous studies have reported only a single litter a year for the Northern Pocket Gopher (Chase et al. 1982) although it has been suggested that the species could produce more than one litter a year in mild climates (Cahalane 1947; Bonar 1995). To our knowledge, this is the first confirmed case of a second litter in Northern Pocket Gophers. The production of two litters by pocket gophers in Alberta is not in agreement with the general life history of the species. In northern latitudes, most breeding activities are complete in June (Runnells 1988; Proulx 2002), and young do not leave the maternal burrow before mid-summer (Proulx 1997). Pocket gophers conceived in mid-summer would therefore leave the maternal burrow in late summer-early fall, when the quality and quantity of green vegetation are reduced (Proulx 1998). The survival rate of these late dispersers would likely be lower than that of juveniles born earlier in the year. The reasons for a second litter in a pea field population are unknown.

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Narwhal, *Monodon monoceros*, Near Western Baffin Island, Nunavut, Canada

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Mallory, Mark L., and Andrew B. Didiuk. 2001. Narwhal, *Monodon monoceros*, near western Baffin Island, Nunavut, Canada. Canadian Field-Naturalist 116(2): 323–325.

In August 2000, a Narwhal, *Monodon monoceros,* was found dead on the west coast of Baffin Island at a location where this species had not been previously documented. The Narwhal was very dark for an adult, and it had an injury on its back that may be consistent with being speared by either a harpoon or by another Narwhal.

Key Words: Baffin Island, Narwhal, *Monodon monoceros,* range, injury.

Knowledge of the abundance and distribution of various wildlife species in arctic Canada is incomplete, in large part due to the isolation of some regions and the expense incurred in surveying these sites. Hence, opportunistic wildlife observations from varied field projects can be of considerable assistance in filling in the gaps in species range maps.

On 8 August 2000 the Canadian Wildlife Service was conducting helicopter surveys of coastal wetland habitats to verify vegetation characteristics identified in LANDSAT 5 satellite images in and near the Dewey Soper Migratory Bird Sanctuary on the west coast of Baffin Island. Four biologists and a pilot used a Bell Long Ranger helicopter equipped with floats, and navigated using GPS. Just north of the mouth of the Koukdjuak River, at 66° 59′ N, 72°49′ W (Figure 1), we observed a dead Narwhal (*Monodon monoceros*) near the shoreline, and we landed beside it to investigate. We knew the Narwhal had washed ashore the previous night, because we had flown over this portion of shoreline at low altitude the previous day on the way to a fuel cache, and on the pale, flat, clay shoreline the Narwhal was an obvious feature.

The carcass was in excellent condition, suggesting a recent death. Blood was flowing from recent pecking at the eyes and blowhole by larid (gull) or corvid (crow) scavengers. Closer inspection revealed two curious characteristics of this male Narwhal. Although we had no measuring equipment with us, we extrapolated measurements from digital photos and determined that the Narwhal had a tusk that was approximately 1.4 m long, and a total body length of approximately 3.9 m, indicating it was an adult (Hay and Mansfield 1989). However, adults of this size and tusk length are typically light coloured on their ventral surface and dark, mottled gray on their dorsal surface (Banfield 1974; Hay and Mansfield 1989). This male had only two small, whitish patches under the

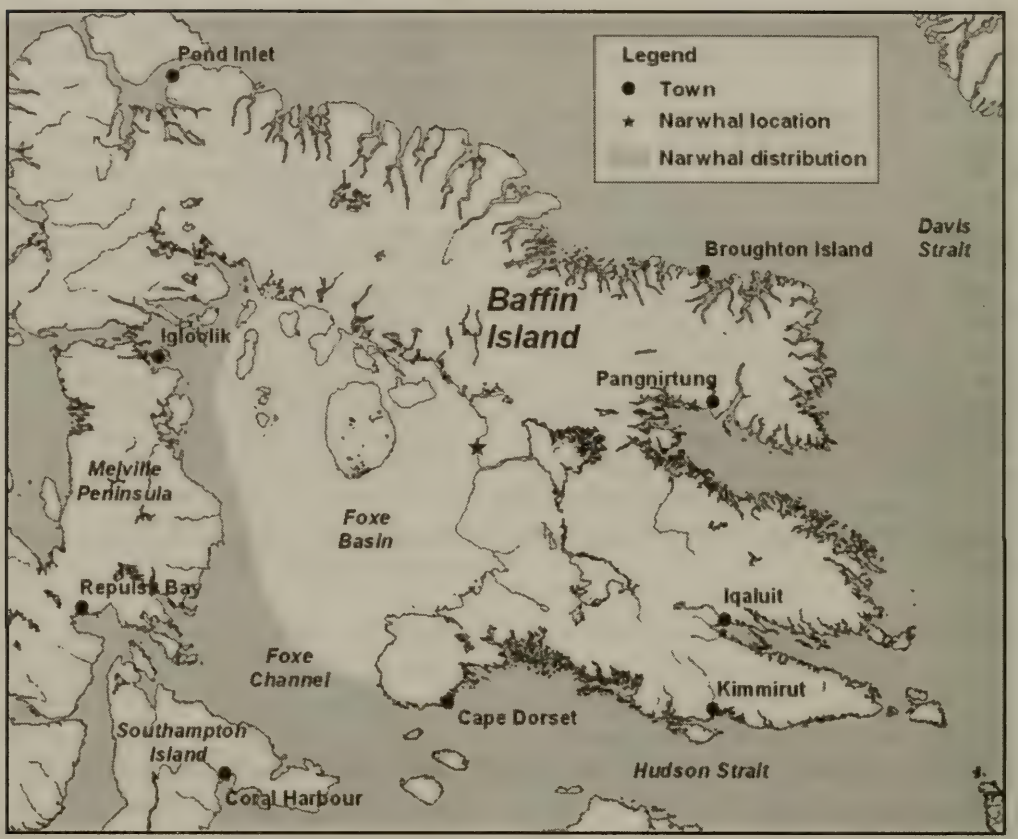

FIGURE 1. Known range of Narwhal (*Monodon monoceros*) near Foxe Basin, and location of our observation.

chin (each approximately 10 × 15 cm), and it was otherwise a uniform mottled gray over the rest of the body, which is an odd colouration for an adult (K. Hay, Nunavut Wildlife Management Board, personal communication).

Also, there was a puncture wound on the dorsal surface of the Narwhal centered approximately 2 cm to the right of the spine. The puncture was almost a perfect, smooth circle with a diameter of approximately 5 cm, and it was clearly made as something penetrated from the dorsal surface directly into the central organs of the Narwhal. We could see 10 cm into the wound, at which point the mass of internal tissues had collapsed and sealed the hole. It did not appear to result from a bite from another animal, and thus we considered three possible explanations: gunshot wound, harpoon wound, or puncture from the tusk of another Narwhal. First, all observers agreed that, given the location, shape and direction of the puncture, the pattern was inconsistent with that expected from a gunshot wound. Second, the wound configuration was consistent with a harpoon puncture. However, if this was an animal that had suffered internal wounds during an Inuit hunt, it would have travelled at least 200 km from the known range of Narwhal and Inuit hunting regions in this condition. Finally, we postulate that the wound could have resulted from a puncture by the tusk of another Narwhal. The function of the Narwhal tusk has been the topic of considerable speculation, but it is likely used as a weapon, as a sexually selected trait that indicates male dominance (Gerson and Hickie 1985), and perhaps for digging for food. One study has reported injury of a female Narwhal from another Narwhal's tusk (Ford and Ford 1986). Unfortunately, in our case the lack of dissection and preservation equipment and the approach of a nearby Polar Bear (*Ursus maritimus*) precluded a detailed examination of the wound, and thus we could not discriminate further between our two possible explanations.

Aside from the curious physical characteristics of this carcass, the location of the finding was also noteworthy. Range maps and traditional ecological knowledge of Inuit in nearby communities suggest Narwhal inhabit western Foxe Basin (Figure 1; Strong 1988; Hay and Mansfield 1989; Stewart et al. 1995). This is the first report of a Narwhal along the eastern coast of Foxe Basin (P. Richard, Department of Fisheries and Oceans, personal communication). It is unclear whether this sighting represents a chance observation of a carcass within the species' normal geographic range, or if instead this was an injured individual Narwhal that strayed from its usual range. Shallow waters and extensive tidal flats are considered atypical habitat for Narwhal (Hay and Mansfield 1989), although they do enter these areas to escape Killer Whales, *Orcinus orca* (Campbell et al. 1988). Nonetheless, with no communities along

this coastline and minimal Inuit hunting in this area, it is possible that Narwhal visit this area of Foxe Basin without detection.

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A Tribute to Edward Warren Greenwood (1918–2002), Canadian Orchidologist

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Ed Greenwood made significant contributions to the knowledge of Canadian and Mexican orchids and their habitats, and was a member of The Ottawa Field-Naturalists' Club for almost 40 years. He died in Ottawa on 24 February 2002, two weeks after his 84th birthday. He is survived by Mary, his wife of almost 60 years.

Edward Warren Eugene Greenwood was born in Toronto, Ontario, on 9 February 1918. He grew up in the rural setting of Stratford, 120 km to the west. During his high school years Ed became interested in the local orchids and in photography, interests which motivated him wherever he lived. With the support of a high school teacher, he built his own pin hole camera. His first photograph was of a Fragrant White Orchid (*Platanthera dilatata*) growing in the fen margin of a kettle lake just east of town. Also while in high school, Ed met Scottish-born Mary Scobbie, a fellow student and his future spouse. He gave Mary a Showy Lady's-slipper (*Cypripedium reginae*) flower for her sixteenth birthday.

On graduation from high school, Ed won a scholarship to study engineering chemistry at Queen's University, Kingston, Ontario. After his first year he worked in industry for two years before returning to his studies. In 1942 he and Mary were married. A year later Ed graduated with a B.Sc. and entered the army. He was sent to Officer Training School and then continued his studies at the Royal Military College of Science in England. After the war he resigned his commission but continued in research and development as a munitions specialist with the Defence Research Board at Valcartier, Quebec, from 1947 to 1959. While at the Valcartier base, he spent his spare time botanizing and photographing his discoveries. He located 14 species of wild orchids within the base perimeter, including the rare Southern Twayblade (*Listera australis*). This population and four others that Ed found in the Quebec City area were the subject of his first scientific paper. Before that, Southern Twayblade was known from only two locations in Canada. After a posting to the Canadian Embassy in Washington, D.C. from 1959 to 1962, Ed and Mary came to Ottawa.

Soon after Ed joined The Ottawa Field-Naturalists' Club in 1963, he got involved in various local activities including organizing and leading botanical outings and study groups, contributing to members' slide nights and serving as guest speaker at the 1966 Annual Dinner. On their own, the Greenwoods ranged through eastern Ontario and western Quebec in their Volkswagen Beetle to find orchids and other interesting plants. In the mid-sixties the Club found itself defending the Mer Bleue peat bog from being turned into a garbage dump and attempting to guide the National Capital Commission to an awareness of the ecological treasures in Gatineau Park and the Greenbelt. Ed realized that it would be useful for conservation purposes as well as for orchidological studies to have a catalogue of the orchid colonies and their locations. And so, in 1966 he founded the Club's Native Orchid Location Survey to seek out and map accurately the orchids within 50 km of the Peace Tower (the Ottawa District). That year he and six others recorded 913 colonies. Buoyed by the success of his initiative, Ed decided to expand the survey work to include the whole of Canada. By the mid 1970s some forty people had generated 3000 records in the Ottawa District and a total of 12 000 for all of Canada. This data has proven valuable in preparing submissions for land use management studies and, in particular, for our monograph on the orchids in the Ottawa District (1997, Canadian Field-Naturalist). We have deposited copies of these records in the Agriculture Canada herbarium (DAO) and the herbarum of the Canadian Museum of Nature (CAN).

When Ed Greenwood was the guest speaker at the 1966 Ottawa Field-Naturalists' Club Annual Dinner, his topic was Mexican Wildflowers. He talked about the flowering plants typical of the various vegetation zones of the country and used slides from his extensive slide collection to illustrate his subjects. Since the late 1950s the Greenwoods had spent Ed's annual leave in Mexico and, being excited by what they found, decided to spend their retirement there. Each year they chose a different part of the country to explore and botanize. Ed expanded on his longtime interest in the cactus family and has a species and a variety named after him. In 1969 the Greenwoods left Ottawa for London, England, where Ed was attached to the Canadian High Commission. During his four years there he spent most weekends at the Royal

Edward W. Greenwood (left) with Mexican field colleague Octavio Suarez in Oaxaca, November 1980. Photograph by Ralph T. Holman.

Botanic Gardens, Kew and the British Museum (Natural History) photocopying all available original literature on Mexican orchids and photographing type specimens. Thus equipped, the Greenwoods moved to Mexico when Ed retired in 1973.

From their base in Oaxaca, Ed and Mary toured far into the surrounding countryside searching for orchids and intriguing habitats. They also hosted and guided many visiting scientists to areas of interest. Ed was an important contributer to the renaissance of Mexican orchidology begun by Eric Hágsater, who revived the Asociacion Mexicana de Orquideologia and its journal, Orquidea, as well as founding a herbarium (AMO). By 1979 Ed was involved in the journal as book review editor and, with Mary, as translator (to English) and unofficial assistant editor. The journal continued to evolve into a fully refereed, mainly taxonomic publication; Ed served as co-editor for Volumes 8 to 16, from 1981 to 2002. Among Mexico's thousand or so orchid species, the terrestrial orchids were the least studied and so Ed focussed his energies on these, especially the genus *Govenia*, but also the genus *Malaxis* and the subtribe Spiranthinae. In all, he described 10 new species and clarified the identities of several others. He wrote the account of *Govenia* for the Flora of North America and advised FNA editor George Argus on various aspects of tropical orchids. After 20 stimulating and successful years in Mexico, Ed and Mary were forced by declining health to return to Ottawa in 1993. There Ed continued to write and to keep in contact with his many friends and colleagues. His remaining papers, two of which are listed in the following Appendix, will be published posthumously. Ed's Mexican colleagues recognize him as the most influential person in contemporary Mexican orchidology. They have already named nine orchid species and one genus after him. The next number of *Icones*

Orchidacearum (Fasciles V and VI, Orchids of Mexico, Parts 2 and 3) will be dedicated to him and will include additional species named in his honour, as well as the two articles he had prepared in Icones format (Eric Hágsater, personal communication). Mexico was Ed's spiritual home.

Ed had a commanding personality, which may be evident in the photograph in Plate 23 of Luer's The Native Orchids of the United States and Canada (1975). He had a good sense of humour and was a great story teller. He will be remembered by orchid taxonomists for his advocacy of working with living plants in addition to herbarium material and his exhortation to pay special attention to the morphology of orchid's reproductive organ, the column. He was insistent that the description be comprehensive and include a detailed technical drawing showing all parts of the plant including several views of the column. Through his enthusiastic promotion of these aspects of orchid study and his eagerness to share information, he had a significant and very beneficial influence on orchid research. His influence as a reviewer and correspondent was remarkable. His energy, enthusiasm, encourgement and expertise, as well as his passion for orchids, will be remembered by many who knew him.

Acknowledgments

We based this account on Ed's publications and his voluminous correspondence with us since 1972; on our memories of our friendship with him from 1967 onward; and on information provided by Mary Greenwood, George Argus, Paul Catling, Bill Gamblin, Eric Hágsater, Henry Howden, Dave Smythe, and Marilyn Light, as well as Marilyn's notes on a 1998 interview with Ed. The photograph came from Eric Hágsater by way of Marilyn Light and Michael MacConaill.

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Genus and Species Described by E. W. Greenwood [*Compiled by* ERIC HÁGSATER]

ORCHIDACEAE

Genus

Cutsis. P. Balogh, E. Greenwood & Gonzales, in Phytologia, 51(5): 297 [1982].

Species

Euchile depatronii Greenwood, Soto & Salazar [in press Icones Orchidacearum]

Euchile hagsateri Greenwood, Soto & Salazar [in press Icones Orchidacearum]

Govenia bella E. W. Greenwood, in Orquidea (Mexico) 10(2): 230 [1987].

Govenia dressleriana E. W. Greenwood, in Orquidea (Mexico) 13(1–2): 165 [1993].

Govenia praecox G. A. Salazar & E. W. Greenwood, in Orquidea (Mexico) 13(1+2): 113 [1993].

Habenaria ixtlanensis E. W. Greenwood, in Orquidea (Mexico) 10(2): 297 [1987].

Liparis draculoides E. W. Greenwood, in Orquidea (Mexico) 8(2): 312 [1982].

Malaxis amplexicolumna E. W. Greenwood & R. González Tamayo, in Orquidea (Mexico) 8(1): 123 [1981].

Malaxis rosilloi R. González Tamayo & E. W. Greenwood, in Orquidea (Mexico) 9(2): 387 [1984].

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New Combinations by E. W. Greenwood

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Schiedeella diaphana (Lindl.) P. Burns-Balogh & Greenwood, in Orquidea (Mexico) 10(1): 93 [1986]: Notes: *Spiranthes diaphana*.

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CACTACEAE

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Ferocactus recurvus var. *greenwoodii*, in C. Glass. Cactus and Succulent Journal (US) 40: 160 [1968].

ORCHIDACEAE

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Epidendrum greenwoodii E. Hágsater, in Orquidea (Mexico) 10(2): 338 [1987].

Galeandra greenwoodiana N. Warford, in Lindleyana 9(1): 39 [1994].

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Lepanthes greenwoodii G. A. Salazar Chavez & M. A. Soto Arenas, in Orquidea (Mexico) 14: 103 [1996]

Liparis greenwoodiana A. Espejo Serna, in Orquidea (Mexico) 10(2): 370 [1987]

Malaxis greenwoodiana G. A. Salazar Chavez & M. A. Soto Arenas, in Acta Botanica Mexicana 10: 46 [1990].

Trichosalpinx greenwoodiana M. A. Soto Arenas, in Orquidea (Mexico) 10(2): 257 [1987]

Additional tribute

Light, M. H. S., J. M. Reddoch, E. Hágsater, and **M. Soto.** 2003. Edward W. Greenwood (1918–2002). Icones Orchidacearum, Fascicles V and VI. Orchids of Mexico, Part 2 and 3. Pages iii–vii.

Book Reviews

ZOOLOGY

Butterflies of British Columbia (including Western Alberta, Southern Yukon, the Alaskan Panhandle, Washington, Northern Oregon, Northern Idaho, Northwestern Montana)

By C.S. Guppy, and J. H. Shepard. 2001. Royal British Columbia Museum book published by UBC Press, Vancouver. 414 pp., illus. $95.

British Columbia has the largest and most diverse butterfly fauna of any Canadian province with 187 species recorded to date. Chris Guppy and Jon Shepard take on the challenge of detailing all the available information on these charismatic species in their well-researched and attractive book. In the last thirty years, books have been published on most province's butterflies. British Columbia is one of the last to produce a comprehensive butterfly book, but in many respects it may be the best. The closest in quality is *Alberta Butterflies*, published in 1995.

The 70 pages of introductory chapters cover such standard topics as the study, conservation, gardening and biology of British Columbia butterflies. They also cover less standard topics such as post-glacial origin, impact of humans, the morphology of immatures and adults, and seasonal changes of the British Columbia butterfly fauna. Where this book excels is in the copious, useful detail. Each chapter is subdivided into appropriate headings to make the information you may be looking for easy to find. I particularly liked the list of butterflies of concern in British Columbia and the series of four maps showing how the glacial icecaps covered the province.

The species accounts make up the majority of the text. Each covers the etymology (the origin and meaning of the common and Latin names), immature stages, biology, subspecies, range and habitat, general distribution, and conservation status. The book is arranged with two columns of text for each page. When you first open the book, it is the visuals for each species that attracts your attention. In addition to half-column size photos of the upper and undersides of the wings for all species, there are full-column excellent pictures from nature of adults and larvae for many species. Each account also has a map of British Columbia and surrounding regions showing detailed dot locations for all subspecies (a unique feature), differentiated by colour. As well, there is a bar graph showing the relative abundance of each species throughout the known flight season.

The final part of the book contains appendices with a species checklist, data and credits for the butterfly photographs and drawings, the Lepidopterists' Society statement for collecting lepidoptera, a glossary, an extensive bibliography and an index. There are also maps showing the distribution of 20 additional species in areas adjacent to British Columbia that could show up in the province. This additional species concept is slightly confusing because there are also full species descriptions in the text for at least seven species that have not yet been found in British Columbia.

As with all such taxonomic books, there are some contentious points. The authors have reassessed the status of several species that differs from the taxonomy of most recent authors. As an example, they treat the population of the Brown Elfin, *Incisalia augustinus,* in southern British Columbia as a separate species, the Western Elfin, *Incisalia iroides*. Also contentious is the use by the authors of common names that have never been used before in the butterfly literature (e.g., Boeber's Fritillary and the Mountain Alpine).

Overall, this is an admirable work abounding in useful information and should be on the bookshelves of anyone interested in butterflies and their role in nature.

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Ecosystem Dynamics of the Boreal Forest: The Kluane Project

Charles J. Krebs, Stan Boutin, and Rudy Boonstra. 2001. Oxford University Press, Oxford. 511 pp., illus. U.S. $152.

The 10-year-cycle of the Snowshoe Hare and Lynx has perplexed and intrigued Canadians for nearly 200 years. Why is it so regular, so predictable?

Yukon's Kluane National Park was chosen for a decade of intensive study of the 10-year cycle, "the main dynamic driving the population trends of larger vertebrate predators," funded mainly by the Natural Sciences and Research Council of Canada. Nine faculty members from three Canadian universities, 26

graduate students, 75 summer assistants, and 18 technicians expended 158 person-years of effort. There were 98 058 field hours of observations by 212 observers and 2780 small mammals were trapped during 24,650 trap nights. Tracks were counted along 12 194 km of transect. All the significant parts of the system, including vegetation, were described and quantified precisely in the same place at the same time.

Experimental manipulation was used to test hypotheses. Do predators control hare numbers, which in turn regulate the vegetation, known as top-down effects? Or do soil nutrients regulate vegetation, which regulates numbers of hares and thereby the numbers of their predators, so-called bottom-up effects? Or are the effects reciprocal?

Every component of the boreal forest community was investigated; five chapters deal mainly with vegetation. Special attention was given to the biomass of hares and ground squirrels and of the main predators, Lynx, Coyote, and Great Horned Owl. Experimental manipulation of fertilizer, use of herbicide to kill vegetation, food supplementation by addition of rabbit chow, exclusion of hares, and attempted exclusion of carnivorous predators, were studied alone, within enclosures, and in combination. Simulations tested 27 individual models.

There was a 26- to 44-fold variation in numbers of hares. Coyotes responded with a 6-fold and Lynx with a 7.5-fold variation. During the decline and low phases of the hare cycle, many predators did not reproduce.

As expected, addition of fertilizer caused spruce branches to grow more, and hare densities went up 1.3-fold. Removal of mammalian predators doubled the number of hares, and addition of rabbit chow tripled their number. Chow addition and predator exclusion together caused hare numbers to rise 9.7-fold, advanced hare parturition dates by 5 to 12 days, and increased the number of young weaned per female hare. Food addition postponed the hare population decline.

Most years, over 90% of adult hares that died were killed by predators, and 65 to 75% of these predator killings were by Coyotes and Lynx. When these mammals were fenced out, Great Horned Owls and Northern Goshawks accounted for 70 to 80% of the predator-killed hares. Great Horned Owls were almost entirely dependent on Snowshoe Hares during winter, killing at least 5 to 10% of hares present in peak hare years, and up to 38% during one year of hare decline (1992-93). Great Horned Owls were competitively superior to Lynx and Coyotes.

There were unexpected findings. Great Horned Owl numbers were limited by food even at the peak of the hare cycle; the owl peak lagged two years after the hare peak. The Northern Goshawk was the only predator that switched from hares to grouse during the hare decline. Unexpectedly, Arctic Ground Squirrels numbers were in synchrony with the 10-year cycle of the hares. Spruce Grouse peaked a year ahead of the hares. Hare browsing stimulated productivity of shrubs, rather than diminishing this food supply. Contrary to expectations, sufficient food was available to hares throughout the cycle. It was expected that ground squirrels and red squirrels would function mainly as alternate prey for predators; instead, to everyone's astonishment, both squirrel species ate little hares, killing up to three-quarters of them at the peak of the hare cycle. These squirrel kills thus helped to prevent hares from overgrazing their food supply. The expected four-year vole cycle, evident in Europe, was not seen at Kluane; Red-backed Voles had major peaks 11 years apart, inversely related to hare populations.

This study provides an almost overwhelming wealth of new information. It offers the first-ever evidence of Lynx and Coyotes acting together as a predator guild, accounting for 78% of mortality of radio-collared hares over 11 years. Coyote numbers were highest at the peak of the hare cycle, but Lynx lagged a year behind. Predators appeared to induce intense stress in hares, thereby depressing reproduction to a degree not previously recognised.

The authors conclude that the boreal forest community is predominately a top-down system. The major changes are driven by predators; predators could not survive in the boreal forest in the absence of hare peaks. Most hares die from predation and very few from starvation. The reasons the cycle averages ten years between peaks still have not been explained, except for a tantalizing paragraph that suggests "intrinsic" programming of hares! Data and computer simulations are supplied on a CD-ROM, supplied with each book purchased.

This book, which provides extremely detailed information about one of biology's greatest puzzles, is an absolute must for all University libraries, in spite of its almost prohibitive price. Those for whom the ten-year cycle has held a lifelong fascination will wish at least to borrow it.

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The Canadian Rockies Guide to Wildlife Watching: The Best Places to See and Appreciate Animals in Their Natural Habitat

By Michael Kerr. 2000. Fifth House Publishers, Calgary. 237 pp., illus. $26.95.

Kerr, a wildlife biologist with the Canadian Forest Service, communicates his love of the Rocky Mountains in a book that is partly personal reflection, partly wildlife biology, partly a travelogue, and most of all a description of the opportunities and etiquette of wildlife observation in the Canadian Rockies.

The book has large print, good pictures and maps, and detailed information about roads, towns, municipalities, and parks. It is divided into four sections, the first of which introduces the idea of the book and why it needs to be written at this time. The second section provides a general description of a large number of fish, reptiles, birds, and larger animals resident to the Canadian Rockies. The third section outlines areas where wildlife may be viewed. Finally there is a calendar showing viewing opportunities in each month of the year, describing migration patterns, and identifying prime viewing locations. Even though a small book on a distinct region, it contains much detail and answers many questions on watching wildlife in the Rocky Mountains.

The book was a fairly quick read suited to an armchair on a quiet evening or as a ready reference on a road-trip, with an interesting presentation style (sometimes tongue-in-cheek) which kept the reading interesting and made me want to go back and read some parts again. As a wildlife and bird enthusiast, I was more interested in his comments about viewing and encountering large mammals and different bird species. As a good biologist and honest reporter, Kerr was frank about the possibilities of seeing mountain goats and large cats up close, or even seeing them at all. This book is not about a safari where all animals are promised and delivered. Mountain goats are rarely seen up close and often with great difficulty even when using a spotting scope to view mountain ledges. Many wildlife enthusiasts living in the mountains have never in their lives had the good fortune to see any of the big cats while always recognising signs of their presence.

Only a few weeks after reading the book I encountered a national newspaper article on viewing the migration of Golden Eeagles. From my reading of the book, I was able to identify the area involved in the article and I was also aware of the background of the recent discovery of the birds in migration, and could compare data in the article to the data reported in the book. His discussion of sighting birds and their migrations was interesting and like a good tour guide made me think of the possibilities of going to view. Fish and reptile viewing were also included to complete the wildlife inventory. Hunting and fishing seasons were mentioned in passing though this is not a book about capturing wildlife on anything but photographic film.

As a further guide to the possibilities of seeing any one of the species named in the book, Kerr has included a "horseshoe" rating to give an idea of the frequency of occurrence of seeing the species. One horseshoe means common sightings, two is less common, three very rare, and four is extremely rare. A wildlife viewer should be prepared with the knowledge of how to identify any wildlife which can be seen but not to expect too much.

After any road journey through the mountains, we invariably ask each other "What did you see?" The answer would be governed by opportunity, most often by luck and occasionally include a sighting which was planned or hoped for. Seeing elk in Banff National Park or the townsite is more probable if you look on both sides of the road. This book teaches in a gentle and entertaining way the appreciation of both sides of the road, the slopes, the creeks, and the seasons of the year. Kerr would include the respect for animals' capabilities to defend themselves or to hide from unwanted observers.

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Four Wings and a Prayer

By Sue Halpern. 2001. Alfred A. Knopf Canada, Toronto. 224 pp. $29.95.

When most people think of butterflies, the first image that usually comes to mind is that charismatic species, the tawny-orange Monarch. The "king" of butterflies continues to fascinate anyone remotely interested in the natural world because of its extraordinary migrations. It has attracted some of North America's best nature writers to chronicle its unique life history.

This book is the latest in the genre and when I first started to read it, I wondered what new insights could be added about this already well-described phenomenon. Well, Sue Halpern has brought a refreshing new approach. She focusses on the people who interact with the butterfly.

The biggest mystery about the Monarch migration is how the species, over at least three generations, finds its way in the fall to a relatively small area in Mexico and then returns as far north as Canada in the

spring. As stated on the dust jacket, Sue Halpern "recounts the mesmerizing story of this mystery and the equally appealing and remarkable people who are attempting to solve it". And she is refreshingly candid about the personalities involved, some of whom I have met and indeed are "characters".

Robert Michael Pyle came out with his own best-seller on the Monarch in 1999 when he published *Chasing Monarchs: Migrating with the Butterflies of Passage*. Pyle, a white-bearded, elfish "character" from Washington State, took a different approach than Halpern. He got into Marsha, his well-travelled Honda, and started "wandering with the wanderers" from British Columbia to Mexico. Halpern takes her own journeys, joining up with the best known of the Monarch specialists and following them around to where the Monarchs fly in Mexico, Texas, New Jersey, Kansas, and Ontario.

Halpern chronicles the relationships among the many Monarch specialists, none more fascinating than that between Fred Urquhart, the doyen and first to discover where the Monarchs overwintered in Mexico, and Lincoln Brower, the distinguished American biologist. Urquhart, from the University of Toronto, had been active for many years tagging the butterflies and attempting to locate the Mexican sites. (As a teenager, I spent a day in fields around Golden Lake in Ontario helping Urquhart stick tags on butterfly wings). Halpern records that Brower was seen by Urqhhart as an upstart and wouldn't shake his hand when they met.

The author also shows how modern technology finds intriguing new ways to expand our knowledge. When not physically with her characters, she tunes into the Internet chat line on Monarchs known as D-Plex (the scientific name for the Monarch is *Danaus plexippus*) where hundreds of individuals around North America record every sighting of Monarchs they make. Halpern also introduces us to two amazing Canadians. Don Davis has tagged more Monarchs than any single person, an estimated twenty thousand, while David Gibo regularly takes his glider plane up into Ontario skies looking for Monarchs to try to better understand their aerodynamics. Halpern takes her fear of flying in hand and goes up with him.

Throughout this well-written and thoroughly enjoyable book, Halpern uses humour and her sensitivity both to the subject and the use of language to weave a fascinating tale of people interacting with this amazing insect. She chronicles how a myriad of amateur and professional enthusiasts have tried to track down and answer the mysteries surrounding the Monarch. Despite this, she laments that "...physicists were going to be able to tell us how the world worked, but we still wouldn't know how a single Monarch butterfly found its way from Canada to Mexico..."

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Radio Tracking and Animal Populations

Edited by J. J. Millspaugh and J. M. Marzluff. 2001. Academic Press, San Diego, California. 474 pp., illus. U.S. $69.95.

This book updates an earlier Academic Press book *Analysis of wildlife radio-tracking data* (White and Garrott 1990). It uses the expertise and experience of several scientists who are knowledgeable in radio telemetry and the analysis of telemetry derived data. Among the authors is Dr. G. C. White, the senior author of the earlier book (White and Garrott, 1990).

Radio tracking and animal populations covers experimental design, animal movements, resource selection, and population dynamics. A chapter on telemetry equipment provides an overview of the technology who is sufficient for the scientist that is concerned mainly with analysis, but should not supersede another Academic Press volume *A manual for wildlife radio tagging* (Kenward, 2001). For this book, Dr. R. E. Kenward has provided an excellent chapter on the history of wildlife telemetry.

One of the best features in the very clean and error free volume is the appendix. This appendix provides a comprehensive listing of software available for use in analyzing telemetry data. The listing includes web sites where information on the various software packages can be obtained, and in some cases the software and documentation can be downloaded. In many cases the appendix provides sufficient information to aid in deciding which program(s) to select for a particular analysis. In addition, the literature cited provides one of the most complete bibliographies of telemetry literature that I have seen in many years.

This book is a must reference for all scientists that work with telemetry or are contemplating telemetry projects. It should be used from start to finish in any telemetry project. Coupled with Kenward (2001), you have at your disposal a complete telemetry library. Academic Press is to be commended for continuing and updating its wildlife telemetry offerings.

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The Birds of Ecuador – Status, Distribution and Taxonomy (Volume I), Field Guide (Volume II)

By Robert Ridgely and Paul Greenfield. 2001. Cornell University Press. xvii + 848 pp. (Volume I) and xvii + 934 pp. (Volume II), illus. Paper U.S. 10$.

I was delighted to hear that a new, two volume set on *Birds of Ecuador* was about to be published because earlier this year I searched for a good field guide to birds of Ecuador, and discovered that this was a neglected area. Les Beletsky (1998) had recently produced a traveler's guide, but this was more of an ecosystem text than a field guide. True it had a field guide section but this covered only the most common birds (plus reptiles, amphibians, mammals and a handful of key insects). As nice as this book is, it would not fulfill the needs of an avid birder. By default I turned to the *Birds of Colombia* (Hitty and Brown 1986). This is a very good guide, with excellent illustrations. However I began to generate many questions. For example, the Colombia guide contains little or no information on Casqued Oropendula, Purplish Jacamar, and Hauxwell's Thrush.

This new publication has now arrived as a boxed set. The first volume deals with distribution and taxonomy and the second is called the field guide. So how well does the field guide work? For a start Volume II is large; 5 cm × 15.5 cm × 22.5 cm (2 in × 6 in × 9.25 in), weighing over 1.5 kilos (almost 3.5 lbs.). The author confronts this issue head on by explaining he needed the size to include all the 1,600 species of birds. However I would disagree for reasons I will discuss later. I believe this volume could be two-thirds to, possibly, half the current size. The balance of the cut material could go in Volume 1.

From a technical point of view, as opposed to the logistics of size, the book fares much better. Finally we have a decent reference to one of the most diverse habitats on earth. Each species has a plumage description of all the salient features and comparisons to similar species. There is a short description of range and a respectably sized, clear range map. There are many species that are not covered or sketchily described in *Birds of Columbia* that are well covered in these volumes. However these books only cover mainland species. They do not include the Galapagos Islands, although some birds are included, as they are visitors to the mainland coast.

There is a colored map of the three main ecoregions at the beginning of the coloured plates. This map is repeated in black and white in the front of both volumes. I found the location of (San Sebastian de) Coca is not correct (it is shown east of Rio Napo, whereas it is on the west side, on the Rio Coca) but other places seem to be positioned correctly. There is no scale given (the reader can assume the colour bar explaining the elevation code represents about 250 km). The major rivers are shown but not named. You will have to identify the Napo, Aguarico, Zamora, and Guaillabemba, etc. to follow the distribution section. These volumes are mostly free of serious technical errors except that the distribution map for Hairy-crested Antbird is repeated. The map for Yellow-billed Tern I think is shaded. It is only possible to see shading with strong magnification. Compare this shading with the easy to view map of the Large-billed Tern, which has a similar distribution. The Black Skimmer is shown only on the Napo whereas the text says it occurs on the Rio Pastaza.

A word is in order about the names and status of some specific species. The Great Mannikin is renamed Varzea Schiffornis as the authors suggest and substantiate that this is a more accurate name. The Yellow-ridged Toucan is lumped with the Channel-billed Toucan and the recent combination of the Red-backed and Puna Hawks as the Variable Hawk is also covered. The authors have also changed some of the scientific names to represent current thinking; e.g., Red-throated Caracara is moved from *Daptrius* to *Ibycter* and Salvin's Curassow is moved from *Crax* to *Mutu*. The information on the White-chested Swift is sparse and the author gives a good explanation of the current sightings and the potential for a change in status. Several other birds that are poorly known may undergo a split when they have received further study. These include the Russet–backed Oropendula (*atrocastaneus* and *angustifrons* subspecies), the look-alike Subtropical and Scarlet-rumped Caciques (the Red-rumped Cacique is also very similar), the eastern and western forms of the Tropical Gnatcatcher, and two forms of the Yellow-rumped Cacique. I was surprised that the author made no mention of a potential split of the White-winged Black Phoebe from the widespread Black Phoebe. Other documents list the

Variable Seedeater as present along the Rio Napo. This author has given this form species status as Caqueta's Seedeater. I have a good reference to a virtually all-black form of this bird and was hoping the Ridgely's taxonomic section would clarify this dilemma. I still remain somewhat confused.

The illustrations are of good quality. The shape and posture of the birds are well captured. I find the colours in my edition over bright. This is not an issue for most species as they are very colourful anyway. How can you make a macaw over bright? It is more of a problem with dull birds, where the shades are more subtle. However, I had no problem instantly recognizing a species for what it was meant to be.

I have always had problems with other people's descriptions of birds' song. This is not the case with this book. I found myself nodding in agreement virtually all of the time. For example, Ridgley gives the Ruddy Pigeon's call as "hit the foul pole." To my ear this is much closer to the sound than "What's the matter?" that I have read elsewhere. I was impressed with the author's description of some sounds I thought impossible to describe (e.g., Paraque). The only exception I could find was Bartlett's Tinamou, but it was within a typical song variation.

I do not agree with the author's view that the field guide volume could not have been smaller. For example, the text for Little Blue Heron in the North American National Geographic guide is only 40% of that in this guide, and is perfectly adequate for field use. I believe the size could be cut in half by cutting out repetition, using cryptic language, and using short forms for oft-repeated word (e.g., A for adult). Indeed for use as a field guide I would have been happy to remove and use just the illustrations with their cryptic text. This 200-page section has most of what I need in the field. To have the illustrations plus the range maps would be even better. I estimate that this would add about 250 pages. The resulting 3 cm × 15.5 cm × 23.5 cm size is slightly larger than the Geographic guide. The author has the perfect answer for what to do with the useful material cut from the field guide. Put it all in volume one.

I have tried carrying volume two in the field and it is far too heavy to cart around. I left it behind after the first two hour-long walk in the cloud forest. I did not even think of carrying it in the rain forest. Instead I used it thereafter as a reference each night and I had no difficulty identifying almost all the birds I saw using the plates and text. I did find that there was some confusion among a few of the Ecuadorian birders, but this appeared to relate to the new names brought about by several splits rather than inconsistencies in the book. My paper copy curled badly in the tropical humidity of the Amazon, but returned to normal once back in Canada.

This book is a long-awaited, long-needed, important contribution to ornithological literature. It is a must for anyone working or visiting Ecuador, Amazonia, and South America and it would make a great gift too.

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Beletsky, Les. 1998. Costa Rica — The Ecotravellers' Wildlife Guide. Academic Press.

Hilty, Steven, and **William Brown.** 1986. Guide to Birds of Columbia. Princeton University Press.

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Sylvia Warblers

By Hadoram Shirihai, Gabriel Garballo, and Andreas J. Helbig; illustrated by Alan Harris, edited by Guy M. Kirwan and Lars Svensson, with photographic editing and field photography by David Cottridge. 2001. Princeton University Press, Princeton, New Jersey. 576 pp., illus. US$75.

This book has been described as one in the series of Helm-Princeton identification guides, and so it is, but here we have a substantial tome devoted to, not a whole family, but to one genus of some 22 species. Yet it is truly an identification guide, with the bulk of the book offering exhaustive detail on the complexities of *Sylvia* plumage variation.

The *Sylvia* warblers are a genus of Palearctic warbler species. The genus has its centre of abundance in the Mediterranean area, and it includes some of the more colourful and eye-catching members of the Sylviidae; a family that is better noted for its rather nondescript plumages and identification challenges. It also includes such familiar British species as the Blackcap [*S. atricapilla*], Garden Warbler [*S. borin*] and Common Whitethroat [*S. communis*].

This is an exceptional book. It has been over a decade in the making, and this depth of scholarship is evident throughout. Innovations, whether in taxonomy or simply in such matters as the manner in which molt sequences are portrayed, all give the sense of having been carefully considered and well thought-out.

A lengthy introduction with a "User's Guide" carefully outlines the plan of the work. This is followed by a 20-page section on the characteristics of the genus, dealing first with phylogeny and biogeography, and then with general biology and ecology. The genus has been the subject of many groundbreaking studies, perhaps most notably on orientation and migration, and its systematics are still the source of debate. This volume does not attempt to

cover the full range of these topics, which are already available in the major handbooks covering the region, but presents an accurate and up-to-date overview. The authors adopt a "modern" version of the Biological Species Concept, recognizing some new species splits, as allospecies belonging to superspecies groupings. All these sections are both packed with information and highly readable.

The extraordinarily detailed species accounts form the bulk of the book. Each is 20–30 pages in length, and starts with a brief introduction, giving a summary of the species and its systematics. The heading of field identification includes a section on potential confusion species, followed by a detailed "Field characters and plumages" and concluding with a section on major pitfalls. All this is condensed into a box with an identification summary. Voice is then covered, with sections on "Practical use" and main repertoire, and copious sonograms. Identification in hand included a discussion on similar species and a figure showing average measurements and ranges. Subspecies taxonomy includes extensive comments on geographic variation and its associated pitfalls. The section on "Moult, Age and Sex" gives detailed descriptions of each of these [using European terminology], with a box giving a key to aging and sexing the species, and with an excellent and innovative plate showing the timing and percentages of wing feather replacement at each moult. Finally each account has headings for general biology and ecology, and population size and trends, and concludes with 2–3 pages of biometrical data.

Supplementing this formidable body of text are plates: a figure giving lively vignettes showing the "jizz and movement" of the species; an excellent plate showing plumages of both sexes and juveniles, and different races as appropriate; 3–4 pages of superb photographs — usually 15 to 20 images — and full-page maps showing both breeding and winter ranges. In all, a major *tour de force*.

My only regret is that this is a volume that necessarily will have limited value for a North American user. But for persons working in this field, or for those planning to spend time in Europe, this will be a valuable addition to the already wonderful range of references available to them. Now if only someone would attack some of our continent's problem species with equal thoroughness and vigour . . .!

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Bats of Papua New Guinea

By Frank J. Bonaccorso. 1998. Conservation International Tropical Field Guide Series 2, Washington, DC (distributed by University of Chicago Press, Chicago). 492 pp., illus. U.S. $40.

This book is the second in a series of new tropical wildlife field guides published by Conservation International. It is a pleasant surprise that the organisms of study are not birds or large mammals, the usual subjects of field guides, but bats! These unique animals are the only mammals that have evolved true powered flight, and a host of associated ecological, behavioural, and anatomical novelties. They are not only interesting from a scientific point of view but also in terms of the conservation of biological diversity and the environment. For example, bats are important components of tropical forest regeneration as seed dispersers and flower pollinators. This is most evident in a developing country like Papua New Guinea, the area of focus for this field guide, which has been able to retain most of its natural and cultural wealth in spite of mounting economic pressure to unsustainably exploit it. This book aims to promote the development of ecotourism and ultimately the preservation of nature.

There are 91 species of bats documented from Papua New Guinea, the country that occupies the eastern half of the island of New Guinea, off the north coast of Australia. This represents over one-third of the 242 mammal species known from the country, making it a very important group from the standpoint of mammal biodiversity. The field guide begins with a general introduction to the bats of Papua New Guinea followed by a chapter outlining the format of the book. There is a glossary for biological terms encountered in the text, and an identification key to species. The bulk of the guide is devoted to the detailed species accounts for all of the bats found in the country. The accounts are separated into two chapters representing the two suborders of bats (Chiroptera). Within the Megachiroptera suborder there is only one family of Old World fruit bats or flying foxes (Pteropodidae), which is further subdivided into three subfamilies. The last chapter is on the Microchiroptera and it is split into eight sections representing the different families, or subfamilies for vespertilionid bats, found in Papua New Guinea. There is an useful appendix of latitudes and longitudes for the 713 localities mentioned in the book, which is followed by a very thorough bibliography for bats found in this region. The field guide ends with 24 beautifully illustrated colour plates of 58 bat species, 16 head and 42 full-body views, by Fiona Reid, and a checklist of the 91 species to keep track of your own personal life list.

Each species account begins at the top of a new page, which adds to the thickness of the book but speeds-up the locating of accounts, with the scientific and common name. If there is a colour illustration, the plate and page number is referenced. Detailed information is provided in four descriptive sections on species identification, geographic range, natural history, and conservation status. One inconvenient drawback is that the distribution maps are grouped at the beginning of each family or subfamily without any page reference in the species account, or vice versa. The last three sections list the localities where the bats have been found, specimens examined by the author, and typical external measurements taken by field biologists. Where available, measurements are separated by sex and age, which is useful information for understanding variation, but unfortunately the average value is not presented as part of the range of measurements.

One noticeable error in publication is the appearance of a chart for frequency of bats at different elevations (Figure 1.6) instead of a chart for different weights. Notwithstanding the minor aforementioned criticisms, I would highly recommended this field guide to any tourist or biologist heading to Papua New Guinea with an interest in bats. This is one group of animals that has an aura of mystery and intrigue, but with this informative and well-illustrated field guide in hand, it will open up a whole new world of exploration to which most people would never be exposed. I look forward to more books in this series on tropical nature.

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A Field Guide to the Birds of Peru

By J. Clements and N. Shany. 2001. The Ibis Publishing Company, Temecula, California. xvii + 283 pp., illus. U.S.$60.

Following closely on the heels of *Birds of Ecuador Volume 1* (Ridgely and Greenfield 2001) I automatically viewed this book in comparison to this other guide. The immediate reaction is that *Birds of Peru* is a true field guide, not like the oversized Ecuador version. True, at 23 cm × 15 cm × 3 cm [9" × 6" × 1.25"] it will not fit easily in a typical pocket but, it will go in your pack. Even more remarkably, the authors have crammed all the known birds of Peru into this one manageable volume. Such a huge number of species has never before been included in a single book. We also have to remember that skulking look-alikes or difficult-to-see high canopy dwellers form a large proportion of the birds covered. To put this in a Canadian perspective it is like observing a few hundred species of Yellow Rail type birds or sorting out finches at the top of 200-ft high trees (the average Canadian White Spruce is 80 ft).

The authors have tried to include all the birds of Peru, including the most recent additions and hypothetical species. Indeed, one species of hummingbird may well be new to science (or a hybrid?). The authors have included species that have recently been split, such as Caqueta Seedeater (formerly lumped with Variable Seedeater) and Nazca Booby (formerly with Masked Booby) or lumped like the Variable Hawk. Yet they have retained the old Cuvier's Toucan *Ramphastos cuvieri* instead of White-throated Toucan *Ramphastos tucanus*.

To keep the book size under control the text is very brief. Generally only a single sentence giving key features is followed by a line on distribution in Peru. World distribution is covered in a single phrase. Where there are difficult identification problems there is additional text; with some of the euphonias and terns for example. There are three maps; one on life zones (in colour), one on protected areas, and a general map. The first two are useful, but you would need a better road map to find the places named in the text. The authors often name specific localities for special birds, but the reader is on his own to find the exact whereabouts (e.g., the Saffron Siskin is at Tumbes). The authors also use the terms parano, puna, varzea, and terra firme throughout. I could not find an explanation of the meaning .of these important ecological divisions.

This guide is, like the Ecuadorian one, another important step in bird literature from a neglected corner of the world. Peru is home to 1800 species of birds, an incredible diversity. So this guide is most welcome. The authors were faced with covering a huge number of species while keeping the book to a manageable size. In this they have been most successful. It did, however, mean a number of compromises. The text gives only the key pieces of information on identifying marks, habitat and range. The only biometric given for virtually all the birds is length. There is no attempt to cover song but the catalogue number of an appropriate recording from the American Birding Association's sales catalogue is given (this means you would have to buy 30 CDs or tapes to cover all the birds).

My copy has a photocopy insert listing the over 80 errors in the book. None of these errors are major but they are irritating. For example, the text omits all the references for the plate showing birds of prey in

flight (16 errors) and for 27 species the plate does not give the text reference. The authors state that this was due to problems during printing on 11 September. However, these are not errors of printing but of proof reading and editing. Personally I would have preferred to delay the printing, rather than mar the impact of the new book. I also found a few additional very minor errors.

The illustrations are provided by a group of artists, with individual variation in style. For a large proportion the simplified style is reminiscent of the original Peterson, a style that works well for a guide. While the overall quality is good there are some problem areas. Some of the birds (Black-browed Albatross, and the boobies for example,) are oddly proportioned suggesting a lack of familiarity of the bird in the field. The colour of some birds (American Oystercatcher, Willet, Cock-of-the-rock, Pied Lapwing) is anomalous. *Birds of Ecuador* has 16 to 17 species illustrated on each plate, compared to about 14 in *Birds of Peru*. Yet the individual illustrations in *Birds of Ecuador* are much larger due to the more imaginative use of space. *Birds of Peru* plates have a large amount of white space. This makes a major difference in the detail shown. For example, The Blue-and yellow Macaw is almost $3^1/_2$ times larger in *Birds of Ecuador*. Another factor I found confusing is that the artists have not been careful about scale. The Blue-and-yellow Macaw is depicted as smaller than the Red-bellied Macaw when it is actually well over 30% larger. I noted this on other pages too; the Spotted Sandpiper is about 10% undersized compared to the nearby Ruddy Turnstone and the Hoatzin is both small in depiction and undersized relative to a neighbouring Cattle Egret.

The plates do not always follow in sequence. The most widely separated species are the terns, being on plates 9 and 23. The black phase of the Vermilion Flycatcher has been put on a separate plate from the common red form. I could have understood this if it were on the page with the other small black flycatchers, but it is with several species of yellow-bellied flycatchers. Overall, however, the illustrations will work well for the intended purpose of this book, and that is to be a field guide

In a book where space was obviously an issue, I am surprised they used so little of the pages facing the plates. The authors use between 25% and 50% of the space to give the English and scientific names plus the page reference. They could have put the single line giving distribution information on this page instead of in the main text, thereby cutting (or freeing) 40 to 50 pages. Incidentally, repeating the scientific names in the text added about 10 pages, enough for a Spanish index. For, although the authors give all the names in Spanish, they do not include a Spanish index. It seems that there is more variation in the Spanish common names than there is in the English. Take stilt for example. Depending on the authority you follow the Common or Black-necked (*Himantopus himantopus*) or Black-winged Stilt (*H. mexicanus or H. h. mexicanus*) has at least five common names in the Spanish speaking world. The authors give those most widely used in Peru.

None of my comments seriously detract from the major contribution the authors have made to ornithology. This is a valuable, useable field guide that will work well in the field and is a must-buy for Peruvians, visitors to Peru, and indeed birders in adjacent countries.

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Birds of Delaware

By G.K. Hess, R.L. West, M.V. Barnhill, and L.M. Fleming. 2000. University of Pittsburgh Press, Pittsburgh. 635 pp., illus. U.S.$65.

When I opened the box in which this book was shipped, I immediately thought, "Wow!" This book, judged by its cover (and heft) is wonderful, and will make bibliophiles ooze with delight.

This is not just an atlas of breeding birds, this is much more. This book incorporates data from many surveys, including the Breeding Bird Survey, Breeding Bird Census, Spring Migration Counts, Christmas Bird Counts, and of course, atlasing work from 1983 – 1987. In addition, data from museum specimens, government and non-government agencies, banding data, nest records are all incorporated. Field records from many individuals, some dating back many years, are also included. In short, with all these sources tapped, this book is a wealth of information that seems to cover all of the aspects of bird distribution and abundance that is available.

Five introductory chapters precede the species accounts. The typical geology/climate and methodology chapters are there; a chapter describing historic records (from the 1630s!), which then follows the progression ornithology in the state, was an interesting read. Although there are plenty of maps in these

chapters, including one map for each of the three counties' highways and population centers, I still felt that one map was missing. A single-page map showing key urban areas, important driving routes, and the frequently birded areas would have been extremely helpful to people not from the state. Every time I read of a birding site, I had to search the three county maps for the names for which I was looking.

Twelve essays, dispersed at key locations throughout the book, bring an interesting perspective to Delaware's birds. There are essays on the history of Breeding Bird Atlases, the largest heronry in the state (Pea Patch Island), the spring shorebird migration, laws concerning birds, and eight others. I liked this idea a lot.

Line drawings (except for the most uncommon species) start each species account. These were drawn by a variety of artists, of a variety of skill levels. I can't understand why a few species are illustrated only by a fledgling, not by an adult. The text briefly describes each bird's habitat, but most of the text is devoted to analyses of migration dates, breeding information, and its distributional history in Delaware. A good amount of text is devoted to the atlasing data, and trends from the various surveys that occur throughout the year. For breeding species, a map is shown with squares in which breeding evidence was found; a second map is often included which shows the relative abundance of the species. CBC data (for the state's five long-running circles) are thoroughly summarized in a table and two graphs; these tables and graphs show absolute numbers found and the more meaningful birds per party hour.

All in all, this is a thorough work. It should be a model upon which other "Birds of ..." books should be based.

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Checklist of the Birds of Northern South America

By Clemencia Rodner, Miguel Lentino and Robin Restall. 2000. Yale University Press, New Haven, CT. 136 pp., U.S.$23.50.

This is a listing of 2245 species recorded in the strip of countries that run from Ecuador to French Guyana across the northern edge of South America. The coverage includes the offshore islands of Aruba, Curaçao, Bonaire, Trinidad and Tobago. It does not include the Galapagos, Isla de San Andres, or Isla de Aves.

The book is set out in tabular form. The listing gives each bird species by its most commonly used English name and its scientific name. There are no Spanish names given. The total number of subspecies worldwide is followed a summary of those subspecies found in the area covered by the book. There is an indication of the general locality of each subspecies The authors have developed a code for the altitudinal range and have a column for general comments (largely for site vagrant records and critical species status). The final set of columns denotes the presence or absence of each species in the individual countries covered.

The list is intended to be a companion to A *Field Guide to the Birds of Northern South America*, not yet published. The author's intent is to provide a definitive list of species and names. They have also noted those subspecies that may be split in the near future.

I was pleased to note that a number of the more recent changes in nomenclature have been included. The Common Piping Guan is split from Blue-throated and Trinidad, the Golden –plumed Parrot is correctly placed in the genus *Leptosittica, Pterglossus erythropygius* and *P. sanguinneus* are separate, and so on.

However, I was surprised to find *Buteo polysoma* and *B. peocilochrous* had not been lumped (this took place a few years ago). The genus name *Stercorarius* has not replaced *Catheracta*, and *Trogon viridus* had not been separated from *T. chionurius*. The authors did not mention the potential split of *Podiceps occipitalus juninnensis* as the Northern Silvery Grebe. *Glaucidium peruanum* is still listed as the Peru Pygmy Owl not the more accurate Pacific Pygmy Owl. These are only a few examples of areas where I was disappointed that the authors had chosen to ignore changes that had been well accepted. I recognize this is a topic fraught with differences of opinion and revision, however I felt they could have been more consistent with emerging practice.

I will await the publication of the field guide before deciding on the usefulness of this publication.

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Birds of Southern South America and Antarctica

By M. de la Pena and M. Rumboll. 2000. Princeton University Press, Princeton. 304 pp., illus. U.S.$24.95.

This was originally published in England in 1998 by Harper Collins as *Collins Illustrated Checklist - Birds of Southern South America and Antarctica.*

This guide covers over 1000 species in Southern Bolivia, Southern Brazil, Paraguay, Chile, Argentina, and northern Antarctica. (central Antarctica is not covered). All birds are illustrated in colour and accompanied by a cryptic text. Range maps are provided at the end of the book. The bird's name is given in English and Spanish or Portuguese as appropriate. However not all the names are up-to-date. For example the "Imperial" Shag complex is out of date (also they are incorrectly called cormorants instead of shags). The Skua complex is in worse shape. The range maps also need a review. The Royal Albatross range is optimistic while that of the Emperor Penguin is extremely optimistic. The range for Turkey Vultures does not include the Falkland Islands, where they are common.

I purchased this book as soon as it came out and used it in both South America and Antarctica. Although it looked like a perfectly good field guide I was disappointed. Several times I was unable to identify a bird species using this book. The illustrations and information were simply inadequate to be certain. On some, but not all, occasions I was able to discuss my problem with an expert or use other texts to resolve the identification. However, I still have two, fairly distinctive birds that I have yet to identify.

I was hoping that this reprint would also be a new version. This is not the case. All that has changed is the cover illustrations and the title. This is an opportunity missed because the original idea was excellent and a thorough upgrade would have improved its usefulness immensely. The handy size and the great coverage would make it a very useful field book if it were a little more accurate.

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Whales and Other Marine Mammals of British Columbia and Alaska

By T. Eder and I. Sheldon (with technical contributions by D. Pattie). Lone Pine Publishing, Edmonton. 160 pp. $16.95.

How many sea mammal field guides do we need for the Northwest Pacific? This field guide alone quotes already four other field guides, and many more can be found on the market. However, this book by Tamara Eder and Ian Sheldon truly justifies its publication. It is nicely written and covers a huge amount of information within the full scope of a highly efficient field guide.

Twenty-six whale species occur off British Columbia and Alaska, but the most prominent species are Grey Whale, Humpback, Orca, Minke Whale, and Harbour Porpoise. For an easy identification, the distinct diving sequences of eleven whale species are provided. For many species, the book shows also major behaviour types (with drawings) to be observed by the whale watcher.

The authors provide well structured sea mammal species accounts, even providing some subspecies information, which is normally not found in other classical field guides. The book considers not only British Columbia but all of Alaska. The superb drawings and photos (for seals) will be appreciated by the reader. But still, even with all this information provided I find Saddleback Dolphins still very hard to distinguish from the Striped Dolphin. Certainly, the subspecies of Saddleback Dolphins, (e.g., Short-beaked and Long-beaked) are still not distinguishable with this field guide, nor with any other. The following species are also very difficult to distinguish: Short-finned Pilot Whale, Risso's Dolphin, False Killer Whale, Northern Right Whale Dolphin, Beaked Whales (Baird's, Cuviers', Hubbs's, Stejneger's), and Dwarf Sperm Whale. Perhaps new field guides and revisions should address these issues specifically in order to advance the knowledge for these species and their conservation?

After reading this field guide the reader will be perfect in all the aspects of "Whale Watcher Talk": The ancient Greeks had already a detailed knowledge and close relation with sea mammals; 70% of the global surface is covered by water; humans are not alone in the world; Endangerment Status of sea mammals according to USFWS and COSEWIC; *Ambulocetus* and *Pakicetus* whale fossils; characteristics and function of baleen; bubble-netting; lunge- and skim-feeding; biomagnetism; sounds and songs; dialects; diving skills; echolocation; whale strandings; intelligence of whales; relation between whales and natives; public perception of whales (from *Moby Dick* to *Star Wars*); dead Belugas treated as toxic waste; and the positive conservation effects of the U.S. Marine Mammals Protection Act. Besides classical "Whale Watcher Talk" and whale records the reader learns in this book also about the value of whale fossils, that ecologically precious Ringed Seal fossils have been found near Ottawa, and that Bowhead whales can live over 200 years.

This field guide raises some interesting points: Are whales for entertainment or for profit? Whale watching along the West Coast creates approximately 5 million $/year, plus 2 million $ for accessory items. With such intense, if not exploitive, whale watching activities, rules are important. As the authors claim, Alaska has the best and most stringent rules to make whale watching safe for the animals. In terms of "true" exploitation, the IWC (International Whaling Commission) and the whaling topic is also covered by the authors in detail; e.g., world-wide, as well as for the West Coast.

Besides sea mammal related information, the authors cover environmental concerns as well. The ocean gets used as a dumping ground, and besides many others, "plastic bag" pollution contributes greatly to sea mammal deaths by blocking their digestive system; the authors quote "*...that millions, or may be billions of plastic bags are discarded every day, many of which will end up floating in the oceans*"! In addition, the authors state that the Northern Sea Lions are declining, and so are Harbour Porpoises.

As the author suggests "*Rare sightings are worth reporting*" but unfortunately, the book does not tell us really how: no survey protocols or suggestions what to report are given. Besides the great text and design, one major drawback comes with the otherwise splendid book: it is poorly bound (glue); in my copy some pages fell out quickly after two days of usage. Here the publishers really need to re-think their decisions.

Nevertheless, I find the authors have produced a very informative and useful field guide, which is lightly and well-written in a very appealing way.

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Guía de las Aves de España

By Eduardo de Juana y Juana Varela. 2000. Lynx Edicions, Barcelona, Spain, 223 pp., illus. 15 euros.

This book is written entirely in Spanish, except that all common bird names are also given in English. It covers all the normally occurring bird species in Spain, and its offshore islands. It is laid out in modern field guide fashion with text on the left and illustrations on the right. Accidental visitors are placed in a section at the back of the book. Please note the English names are European not North American; e.g., Diver not Loon. Frequently the qualifier we normally use is dropped; e.g., Black-crowned Night Heron is simply Night Heron. Oddly the Spotless Starling is listed as "Starling" while the common Starling of Europe and America is also given the same name. Surprisingly Sabine's Gull is given as *Larus sabini* instead of *Xema sabini*. In addition, I noted that where the same or a similar species occurs in South America such as Great Egret, Skua, and Stilt there was hardly any conformance in the Spanish names.

The text is well organized and provides the typical information needed in the field. Included within the text are range maps giving summer, winter, and migration locations. The range maps include the immediately adjacent areas in southern France and northern Africa. A general map identifies the location of the top 50 areas to visit. Those people who do not know any Spanish at all will find the maps and illustrations useful. If you are willing to learn a few words (the colours, the seasons, and bird body parts primarily) the text is logical enough to follow the sense in general. Even a limited knowledge of Spanish will suffice to allow you to get a lot out of the text. The songs ("Canto" in Spanish) are onomatopoeic, so are easy to follow. The authors include the current best estimate of population. This is a great innovation that I hope others will copy. It allows you to understand the differences in viewability with, say Bearded, Egyptian and Griffon vultures.

The illustrations are well done and accurate. These include a rendition of juvenile, summer or winter plumages and subspecies where these are meaningful. Some juveniles are not depicted, notably some of the gulls. I was particularly impressed by the shape and attitude portrayed. It showed the artists were familiar with the bird in the field. The tougher groups (the warblers, shorebirds, pipits, and larks) are perhaps the best test and I had little trouble recognizing almost all species. I only had trouble with a couple of localized species with which I am not familiar.

The 113 accidental species that have occurred in Spain less than 20 or so times are recorded at the back of the book, but only 36 are illustrated. (The Glaucous Gull has been seen 63 times, but most of the other species are limited to one or two sightings.) I was surprised to see that Common Redpoll (*Pardillo sizerin*) has only been found once, in 1993.

This is a wonderful, little, pocket-sized book that is well written and accurately illustrated. It will be most useful to residents of Spain and nearby communities and to all visitors.

Este libro está escrito enteramente en español con excepción de los nombres comunes de pájaros que también estań en inglés. Cubre todas las especies de

pájaros que occuren normalmente en España y sus islas costeras. Está presentado como una moderna guía de campo, con el texto a la izquierda y las ilustraciones a la derecha. Especies accidentales aparecen en la parte posterior del libro. Éste es un excellente libro, tamano bosillo, muy bien redactado y con ilustraciones verîidicas. Será muy útil para los residentes en España y las comunidades vecinas, y también para los turistas.

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BOTANY

Magical Mushrooms, Mischievous Molds

By George W. Hudler. 1998. Princeton University Press, Princeton, New Jersey. 248 pp., illus. U.S.$14.95.

This is an easy to read, nontechnical book that focuses on the effects fungi have and are having on man. The names Mushrooms and Molds refer to two specific groups of fungi. The facts are often presented with a good deal of humor and there is a minimum of technical terms. There are chapters on what makes up a fungus and how they are named; what fungi do and how they do it, that is how they grow, how they get nourishment, what enzymes they produce to break down their food, how they fruit (produce the mushrooms), and how spores develop. What fungi use as food is a principal theme because of the losses to humans when fungi consume (eat) plants, grains, etc. that we grow for food.

Several chapters deal with fungi that damage or destroy our food and the forests. Brief but interesting discourses treat the Potato Famine in Ireland and its effects on North American demographics, the Powdery Mildew of Grapes that nearly destroyed the wine industry in Europe, and the Rust diseases of wheat and their potential impact on the world's food supply. Also discussed are catastrophic tree diseases, such as Chestnut Blight, Dutch Elm Disease, and White Pine Blister Rust, that resulted when spares of fungi were inadvertently brought into North America by the activities of man. An entire chapter is devoted to Ergot, a disease of cereals and grasses, not because it is a major problem but to explain the various ways the fungus has influenced man. Eating the bread from such flour contaminated with Ergot can cause poisoning ranging in seriousness from hallucinations to loss of limbs and agonizing death. The cause of the Salem Witch Trials and the gruesome disease of man called St Anthony's Fire have been attributed to Ergot poisonings. Additional topics that are the subject of individual chapters are mycotoxins, mycoses, medicinal molds, yeasts for baking and brewing, edible and poisonous mushrooms, hallucinogenic mushrooms, wood decay, fungi and insects, and symbiotic relationships between fungi and plants.

Finally, a few critical comments. On page 200 it says the Dry Rot Fungus (*Serpuls lacrimans*) does not occur in the western hemisphere, but a 1993 reference lists it from 37 States and 7 Provinces. Although dry rot is widespread in North America, poured concrete foundations that are waterproofed, and central heating prevent Dry Rot Fungus from becoming a major problem. Although the color pictures are very good, the quality of the black-and-white figures varies greatly. The drawing (Figure 10.3) labeled *Hericium erinaceus* is not that fungus but *H. ramsoum*. And the title of the associated paragraph (page 162) would be more accurate if the word "erinaceus" is changed to "species" because there are four *Hericium* species in North America, all are edible and several are more commonly found that *H. erinaceus*.

Most naturalists recognize a few mushrooms but know little more of the fungi. Professor Hudler's book provides a broad view of the fungi and is a good beginning toward understanding how fungi impact birds, wildflowers, trees, and many other aspects of the natural world.

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Spatial Pattern Analysis in Plant Ecology

By M. R. T. Dale. 1999. Cambridge University Press, New York. 326 pp., illus. Cloth U.S.$69.95; paper U.S.$35.95.

As the title of this book aptly suggests, *Spatial Pattern Analysis in Plant Ecology* is a review of techniques used by ecologists to study spatial patterns of plant populations. The book has nine chapters, covering a wide spectrum of techniques. The first two chapters are introductory, outlining concepts that underlie spatial analysis and sampling techniques. Titles of the remaining chapters illuminate their contents: Basic methods for one dimension and one species, Spatial pattern of two species, Multispecies pattern, Two-dimensional analysis of spatial pattern, Point patterns, Pattern on an environmental gradient, and finally, a concluding chapter. Techniques described throughout these chapters include semivariograms, correlograms, fractal analysis, spectral analysis, and blocked, paired, and local quadrat variance analysis, among others.

In the preface, Dale states that the book is designed to help the reader understand the concepts and methods of spatial pattern analysis. *Spatial Pattern Analysis in Plant Ecology* is part of the Cambridge Studies in Ecology series, which presents up-to-date reviews of topics within ecology, and is aimed at "advanced final-year undergraduates, graduate students, researchers, and university teachers, as well as ecologists in industry and government research". Dale's book certainly meets this standard, although I would add a caveat that the greatest benefit will be obtained by readers who have an understanding of statistical methods but are reasonably new to the world of spatial analysis techniques. Dale presents a good, thorough review of techniques. However, rather than an in-depth description of particular techniques, the book contains an introduction to a broad range of material. In each chapter, the basic logic and fundamentals of a technique are described, often, but not always, including equations. This description is usually supported with examples from the literature, and citations of sources to which the reader could refer for more details. The figures are simple and supportive of the concepts in the text. There are few worked examples.

Although *Spatial Pattern Analysis in Plant Ecology* is aimed at plant ecologists, the methods described are applicable to a range of systems and taxa. Thus, its scope is broader than plant ecology. The more traditional analysis methods, such as blocked, paired, and local quadrat variance analyses, are covered in greater detail within this book, than are more novel techniques, such as geostatistics, wavelet analysis, landscape metrics, and fractal analysis. Indeed, promising techniques such as lacunarity analysis and variance partitioning ordinations receive only passing references, and tree regressions are not mentioned at all. On balance though, the book is full of good ideas and methods and, because of the referenced examples, is a fine starting point for those who are new to spatial analysis. I recommend *Spatial Pattern Analysis in Plant Ecology* for such an audience.

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Rare Vascular Plants of Alberta

By Linda Kershaw, Joyce Gould, Derek Johnson, and Jane Lancaster. 2001. The University of Alberta Press and The Canadian Forest Service, Edmonton, Alberta xliv +484 pp., illus. $29.95.

This is a fascinating book which will catch the eyes of many individuals who have previously not paid much attention to the plants that grow around them. In it is information about 485 species which are of rare occurrence in the province of Alberta, a large percentage of the total known to occur there. The book is divided into sections; an introduction which is followed by the treatments of Trees and Shrubs, Monocots, Dicots, Grass-like Plants, Ferns and Fern Allies, Addendum (which includes a few plants found since the main text was completed in 1998 and two deletions), Appendix 1 (Keys to rare *Botrychium* and *Isoetes* found in Alberta), Appendix 2 (Rare vascular plants of Alberta by Natural Region), Appendix 3 (Species in this guide that are not found in the *Flora of Alberta* (second edition) — New Discoveries and changes resulting from taxonomic revision), Appendix 4 (Taxa previously reported as rare for Alberta but not included in this book), Appendix 5 (Species reported from or expected to occur in Alberta but not yet verified), Appendix 6 (Alberta taxa classified as nationally rare by Argus and Pryer (1990)), Appendix 7 (Rare native plant report form), Glossary, References, Index and Photo Credits.

In the main text most pages include information on only one rare plant: common name, scientific name, family name, descriptive information, habitat, and notes of special interest. On each page the colour photographs, line drawings, coloured distribution maps, and maps of North America which depict other provinces where a species is rare or common are all most important and make this book

so very attractive. The four editors and their many assistants are to be congratulated.

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ENVIRONMENT

The Global Environment in the Twenty-First Century: Prospects for International Cooperation

Edited by Pamela S. Chasek. 2000. United Nations University Press, Tokyo. xi+465 pp., illus. U.S.$39.95.

This book focusses not on the biological environment which naturalists love but on the political and economic challenges facing its survival. The contributors are international experts in environmental policy and its bureaucratic aspects. The piecemeal progress on environmental issues is examined through the roles of five types of actors. Under states and their sovereignty, the review includes energy in India and China (especially, of course, the Three Gorges Dam), issues before third-world cities (with Brazilian examples of successes, such as as Curitiba's infrastructure, and failures, such as Rio's pollution agency), and temporal trends such as leapfrogging technological innovations to new forms like photovoltaics. Under civil society, and its reflection in non-governmental organizations, there is much fascinating material. The power, presence, and alliances of these sovereignty-free "views from nowhere" are demonstrated in a range of impacts including waste treatment by states, disposal of industrial oil rigs, and social mores such as the Canadian hunt on harp seals. In terms of accountability and performance in relation to governments and industry, of advocacy and service, and of drawing on science, non-governmental organisations (NGOs) are the stars of the show. By contrast, under markets, the disastrous consequences of unconstrained activity dictate the need for meta-market vision and knowledge, global governance, and full-cost pricing. Canadians will find the chapters on freshwater, in which it is argued that it must be given a price, and on agriculture, much changed under the new GATT, most interesting. Under regional arrangements, efforts to cope with massive problems, especially in Africa, Asia, and Eastern Europe, are considered. Issues range from loss of natural habitat to the impact of "trade, not aid" policies. Under international organizations the focus is on track records of the World Bank and the UN Environmental Program (UNEP) and Commission on Sustainable Development. In the Conclusion Chasek provides a synthesis of the dominant themes of public attention, governance, conflicts, and flawed markets, to extract some potentially fruitful directions.

The chapters are well documented, with a happy balance of description and analysis. Figures and tables are used effectively, although some chapters give More Than You Ever Wanted To Know. The evenness of discussion does credit to the editor. The four pages of collected acronyms are invaluable. Would it not have been indicative of the new awareness of environmental linkages to use economic "externality" in quotes? It is good to see dialogue between chapters, often lacking in multi-authored works. For instance, whether UNEP scaled up to some sort of World Environmental Organization would solve certain existing problems is argued between chapters.

As a product of the UN, the book pays particular attention to the current and potential roles of that organization and its agencies, as well as to topics and areas beyond the first-world. And surely the world must move from soft motherhood declarations to hard agreements with teeth. This book provides an in-depth examination of the international structures and dynamics for such environmental policy. The contrast between actual crises, natural and human, of conservation and education, and the glossy bureaucracy intended to deal with them is stark. Against the good news, such as the acceptance that national sovereignty should not prevent joint action, is a much larger stack of bad on the Aral Sea, the African Matatuine District, and on and on. Most valuable in this book are the recommendations, in various chapters and the Conclusion, which outline possible courses of action.

The set of existing agencies and treaties is already labyrinthine, and it is difficult to see how to add effectively to it. Much more deeply worrying is the impression that the entire apparatus is functioning, and can only function, as reporters and cheerleaders while the environmental destruction continues apace.

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Reading the Entrails: An Alberta Ecohistory

By Norman C. Conrad. 1999. University of Alberta Press, Calgary. xviii + 197 pp. $19.95.

Reading the Entrails is best described as a good rant. Beginning with the Wisconsinan glaciation and carrying the story through to the reign of the Albertan Conservatives and Ralph Klein, Norman Conrad provides an intensely personal look at the ecological history of the province and the irreversible damage that has been wreaked in only a few generations. His spirited — some might say, relentless — style makes for a provocative read. But it is also an uneven, at times frustrating, analysis.

Conrad makes some questionable statements about the coming of agriculture to the western interior in the nineteenth century. He suggests, for example, that small-scale commercial farming was already underway in the early 1800s, that the fur trade ended in 1870 with the transfer of Rupert's Land to Canada, and that First Nations did not understand the treaties and were "effectively eliminated" as a people in a few decades. His assessment of the region's development during this period is also firmly fixed on the open grasslands; his gaze rarely extends north to the boreal forest and activities there in the nineteenth century.

Conrad is much better in describing developments in the post-World War Two period, especially in the provincial north. He raises some fundamental questions about the nature and impact of Alberta's petrochemical and forestry industries. He also wonders aloud whether society can really afford the costs of a resource-based economy in the long run. Clearly, the environment cannot; according to Conrad, at the current pace, there will be nothing left to do in the near future but "read the entrails" of a once richly diverse environment. And that's why this book should be read by anyone seeking some alternative perspective on Alberta's relationship with the land.

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Spatial Optimization for Managed Ecosystems

By J. Hof and M. Bevers. 1999. Columbia University Press, New York, NY. 258 pp., illus. Cloth U.S.$65 in U.S.A., U.S.$75 elsewhere; paper U.S.$30 in U.S.A., U.S.$34.50 elsewhere

Spatial Optimization for Managed Ecosystems is part of a series called *Complexity in Ecological Systems*. Other well-known titles from this series include *Toward a Unified Ecology* (Allen and Hoekstra 1992) and *Ecological Scale* (Peterson and Parker 1998). With *Spatial Optimization*, Hof and Bevers demonstrate the use of mathematically programmed optimization models to determine strategies for optimal allocation of resource management interventions. Optimization models have much in common with simulation models, but optimizations are different in that they are intended to accommodate and reduce a large number of possible scenarios to a set of manageable options. Whereas simulation models frequently are developed to deal with spatial structure, few optimizations methods accommodate spatial considerations. This book is a novel demonstration of the potential utility of spatial optimization.

The book is divided in four parts: (1) Static spatial relationships; (2) Spatial autocorrelation; (3) Dynamic movement; and (4) Diversity and sustainability. Within each of these sections, information is presented in a modular format, where similarly structured modules present spatial optimization approaches to a range of increasingly complicated management problems. Optimization models that use integer and non-linear programming are used in all scenarios to find the optimal solution, where optimal is defined as an approach that meets all stated management constraints simultaneously. Management problems presented are diverse, and include such things as wildife-habitat relationships, timber harvesting, pest control, and water runoff. Regardless of this diversity however, the same modular approach is taken to each problem. This presentation successfully demonstrates optimization, as it becomes obvious to the reader that a similar spatial optimization approach can be applied to a wide range of management problems. A number of interesting examples are provided, such as optimizing Black-footed Ferret, *Mustela nigripes*, reintroduction in South Dakota. These provide useful context for the reader.

Although the approaches outlined in *Spatial Optimization* have potential for great utility to resource managers, readers are faced with some challenges in processing the material. Foremost, as with any modelling exercise, optimization models are contingent on a number of assumptions. These vary with the application but are of the typical sort, such as specifying the shape of dispersal distributions. Hof and Bevers are explicit about these assumptions, which is a strength of the book, but the reader will nonetheless note that decisions made in light of assumptions could be incorrect. Further, as complicated as these models are, they still oversimplify systems, frequently omitting complicating

dynamics such as competition or predator-prey interactions. Finally, readers of this book (and potential users of spatial optimization) will be faced with somewhat dense discussions of integer and non-linear computer programming.

The methods described in *Spatial Optimization* are challenging, but they have potential for great utility in solving management conflicts. As such, I recommend the book for readers who have a serious interest in resource management.

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The Amber Forest

By George Poinar Jr., and Roberta Poinar. Princeton University Press, Princeton, 2001. 239 pp., illus. U.S.$29.95.

Historically, "the ancient Greek poets", says early 20th century gemmologist George Kunz, "the grains of amber were [considered] the tears annual shed over the death of the brother Phaethon by the Heliades after grief had metamorphosed them into poplars growing on the banks of Eridanus" (Kunz 1913 [1971], pages 55-56). We now consider amber not only as artifacts of past cultures, but evidence of life long before humanity. The most prolific investigator of the contents of amber is George Poinar (see *Quest for Life in Amber* and *Life in Amber*), and with Roberta Poinar, their most recent, colorful, tome is *The Amber Forest*.

The subtitle of this recent work, "a reconstruction of a vanished world", is a geographically restricted examination of amber found on the Caribbean island of Hispaniola. The amber, however, has a broader range, covering a time period from 15 to 40 million years ago. Collecting these samples are amber miners. And the mines "are little more than small, tortuous tunnels carved into the sides of the mountains or sometimes pits sunk deep into the ground" (page 6). The rewards are often sold to the highest bidder. By examining the collections, both in museums and in private hands, the Poinars illustrate unique snapshots of the past; features we more often than not could never see by other methods of fossilization.

The Amber Forest, however, is not a general read. It is a systematic look at the flora and fauna found in the fossilized sap. From plants and seeds, to insects (of all shapes, sizes, and types), to frogs, lizards and snakes; all have left traces or whole bodies in amber. Who would not be moved at a specimen of *Sphaerodactylus*, a gecko lizard, in amber, skin and all, with a partially chewed leaf. "Could the notch on the leave have been made by an insect the gecko attempted to seize?" ponder the authors. Literally or metaphorically "frozen" bodies often lead us to these kinds of thoughts and questions.

Despite the group-by-group framework of this volume, the 171 black-and-white, and 171 colour photographs are spectacular. Kudos to nature for providing us with these examples of past life, and to the photographer for capturing these images. It is no wonder that many of these objects are often considered works of art. Supporting the text and photographs, are black-and-white illustrations of the inhabitants of this ancient tropical forest, as they appeared in life, as they interacted with other occupants of the same ecosystem.

Unfortunately, we are unable to fully realize the wealth of information available in samples of amber. Many of the finer specimens are sold privately and are not seen by scientifically trained eyes. What we do know, what *The Amber Forest* vividly illustrates, is that the possibilities of unveiling nature of the past are seemingly endless.

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Kunz, G. F., 1913 [1971]. The Curious Lore of Precious Stones. Dover Publications, Inc., New York. 406 pages.

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The Natural History of an Arctic Oil Field, Development and the Biota

Edited by Joe C. Truett and Stephen R. Johnson. 2000. Academic Press, San Diego. 422 pp., illus. U.S.$ 69.95.

"Oil Exploration and Development ... result in environmental change". This excellent book describes and investigates these topics, but also further introduces and consolidates human activities and oil development in ecological research and natural history; it sets new publication standards on this subject and polar research, e.g., to be followed in the Russian Arctic and elsewhere.

For the Alaskan Arctic, industrial development and oil production started 50 years ago. In 1968, the

Atlantic Richfield Company announced the discovery of a major oil accumulation near Prudhoe Bay, Alaska. But already in 1969, the U.S. government passed the National Environmental Policy Act (NEPA) requiring the full disclosure of the environmental costs of major development ventures. This needs to be seen in the context of Prudhoe Bay being among the largest oil and gas discoveries in the history of North America. Oil from the Alaskan Northern Slope contributes to the approximately 85% of the Alaskan state budget derived from taxes and royalties. Besides Prudhoe Bay having the oldest oil fields in Alaska's Arctic, Prudhoe Bay also provides over 20% of the USA oil production.

Based on "Oil Field Research", the book consists of 19 research papers (no abstracts) from 27 authors (contact addresses provided) which are mostly associated with universities or with international high-caliber research consultancies such as LGL Ltd. (including the editors) and others. Published by an international high-quality publisher (Academic Press), all of the papers are (externally) peer-reviewed except for the Introduction, North Slope Development and the Synthesis; this assures objectivity of the science presented. Research and publication costs were carried in part by BP Exploration (Alaska) and others, who also set up the focus of the book and authors.

This research publication describes almost all major aspects of wildlife (except for sea mammals, raptors and jaegers) related to oil development and production over the last 20 years and beyond. Divided into four parts, the chapters deal with fish, wildlife, communities, and habitats of the terrestrial and marine ecosystems. The book gives the reader a realistic overview about environmental assessment, industrial (Arctic) research, and governmental regulation and planning processes. It presents nicely and detailed the Environmental Training Programs required for (oil-) field personal, and it shows the mitigation measures which oil companies undertake.

The "Boulder Patch", also a location of major oil and gas reserves off Prudhoe Bay, is THE most diverse marine area in the Beaufort Sea. Due to the oil development the Prudhoe Bay region has finally received more research attention than any other and similar locations, e.g. Arctic Canada and certainly Newfoundland (Hibernia) and Gulf of Mexico. As with any oil impact study the monitoring, pre-spill, and pre-development data are very crucial, but rarely available; some are presented in this book. For instance, research in Prudhoe Bay has resulted in major biological, long-term data sets (hopefully made available soon to the global community via Internet/WWW): 18 years of fish data in the Beaufort Sea, 14 years of Snow Geese research, and what may be the only long-term data set on shorebird migration. Prudhoe Bay has received a very detailed geo-botanical mapping, including the most extensive benthic sampling done anywhere in the Beaufort Sea. Nine years of long-term studies on fish populations in the study area allow for strong capture-mark-recapture analysis and powerful results. Besides others, the study area has a wonderful long-term Polar Bear Satellite GPS study, and a very detailed description and summary of the Grizzly Bear population. Several Caribou herds exist in Alaska [e.g. Western Arctic Herd, Central Arctic Herd (CAH), Tesehkpuk Lake Herd, Porcupine Herd], but only the CAH is really located within the Prudhoe Bay Oil Field area. The Caribou papers present a great summary of Caribou research, and they are a solid resource for references. It is shown that Caribou numbers increased in recent years. They do use oilfields to avoid mosquito harassment; but the impact of roads and elevated pipelines on Caribou migration and biology is unclear and currently in debate.

Changes brought by humans to the Arctic are normally centred around (i) addition of gravel, (ii) disruption of tundra surfaces, (iii) creation of impoundments, and (iv) introduction of elevated structures. Oil development clearly improves human access to wildlife, such as Grizzly Bears. If not regulated, this can result in increased (hunting) pressures and disturbances. The availability of garbage affects Arctic Foxes, which have high densities in the Prudhoe Bay area; a simple removal of these predators with traps remains doubtful. For the study area, the book reports dramatic increases of Black Brant in the 1980s, Red-necked Phalarope show high densities in impoundments, and Grizzly Bears are more productive on oil fields (but the offspring is also more likely to be killed). Although the oil production area "P Pad", built in the 1990s, is already much smaller than "A Pad" (built in the 1970s), much of the research presented still deals with the gravel (road) effects. Impoundments have indeed more nutrients than natural waterbodies; culverts can improve/restore fish migration. As a major impact of oil development, population increases are observed for several shorebird species, Black Brant, Snow Goose, Tundra Swan, Caribou, Grizzly Bear, Polar Bear, and probably Arctic Foxes; but Dunlins declined.

However, the study area of Prudhoe Bay was definitely not untouched and "virgin" before oil development occurred: Muskox were introduced, Polar Bears were hunted from the air between 1967 and 1974, strychnine was widely used to exterminate Wolves but also killed non-target animals such as Grizzly Bears and Squirrels. An historic shorebird hunt existed all over North America, and Eider Ducks and other wildlife were hunted by natives.

The papers of the book give excellent overviews or summaries, but sometimes they don't show methods in full detail. Some of the study objectives and

designs are somewhat worrisome for ecologists; for instance, studies presented have a strong focus on animal abundance and charismatic or huntable species. However, this appears to be in the interest of the general public. Low-level flying, viewshed effects, environmental ethics, and individual animal suffering due to oil development are not addressed. This might confirm that research designs were driven by questions directly of service to the oil industry, but not necessary designed to investigate purely ecological and natural history research questions. Some sample sizes interpreted are quite small, power-tests to evaluate population trend statements are missing, and DISTANCE sampling to survey abundances was never applied. Studies dealing with ecosystem energy flux and predator-prey balances, (e.g., 'exploding' abundances of wildlife and predators), are somewhat lacking. Impoundment effects on ecosystems are unlikely to be fully understood with simple comparisons and experiments. Almost all papers include unpublished reports (grey literature) from over 20 years of consultant contracts, but perhaps they should be specifically quoted and marked in the research papers, as done elsewhere and in similar publications.

The photos in this book are beautiful (some enlargements would have been excellent); for my taste, some maps are a little repetitive in their content. Finally, it would have been nice to have an overview about research gaps, and urgently to be investigated conservation needs and threats for Prudhoe Bay, as well as a detailed list of all oil spills that have occurred.

Although not all ecological questions are fully investigated in this book and are sometimes referred to as "unstudied", some extremely important management questions are raised in this publication landmark: "The assumption of habitat limitation on the breeding grounds is not based on evidence, but rather is a conservative approach to shorebird conservation given the lack of basic population information on most species involved". That quote from the book is a classic statement valid for most migratory species, and might well summarize the current (lack of) knowledge in population studies. Here another "wildlife classic" raised in this book: does simple (bird) abundance equal (nesting) densities ? Obviously, and as the book suggests, consistent and meaningful survey methods for better science and management are required. Despite the major research efforts presented, the following citation might prove to show how weak our knowledge can be even after long-term studies: "We believe that the presence and activities of humans in the oil fields have had little or no population-level impact on species ..., although data currently are insufficient to confirm this belief".

Nevertheless, the authors can be congratulated for their outstanding product. A complete index, and an Errata with only six (!) minor corrections, complement this excellent book and make it a perfect reference, description and template for similar studies and publications. What will the future bring for Prudhoe Bay and its oil development endeavors? With such type of research effort and publication one could rest assured indeed.

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MISCELLANEOUS

Finding Order in Nature: The Naturalist Tradition from Linnaeus to E. O. Wilson

Paul L. Farber. 2000 Johns Hopkins Introductory Studies in the History of Science. Johns Hopkins University Press, Baltimore. 136 pp., illus. Cloth U.S.$39.95; paper U.S.$15.95.

Paul Farber has done it again! In his latest book he tells succinctly how natural history has yielded the major unifying theory of the life sciences, uncovered some of the deepest insights into nature, led us to concern for the environment, and attracted public interest for more than two and a half centuries. Animals were named in *Genesis* but natural history did not emerge as a scientific subject until the eighteenth century.

Farber begins with a Swede, Linnaeus, his conception of order, and his view of creation as a balanced and harmonious system. Linnaeus's students, his "apostles," amassed great collections. Although the Linnaean classification system was artificial, his binomial nomenclature became the universal world standard.

A Frenchman, Buffon, shared the birth-year of 1707 with Linnaeus, but outlived him by ten years. He developed the Jardin du roi, in Paris, as the foremost institution in its day for the study of the living world. Buffon's 36-volume encyclopedia of animals was the second most frequently owned item in private libraries in France. Buffon gave less emphasis to classification than did Linnaeus. He considered nature, not God, to be the generative power.

Collectors soon circled the globe to send back specimens to museums in major European cities.

Advances in paper manufacture and printing allowed artist-naturalists such as John Gould and John James Audubon to publish small editions of large, beautiful books. Scientific journals began and by about 1850 natural history had begun to divide into disciplines and sub-disciplines.

A German, Alexander von Humboldt, emphasized measurement, visual representation, and the search for laws that dealt with nature. However, Paris remained the international hub of natural history through the first half of the nineteenth century. Saint-Hilaire studied comparative anatomy to demonstrate the similarities and differences between different animals. Cuvier described the mass migrations and mass extinctions that had occurred in the geological past. Charles Lucien Bonaparte ruled as the greatest expert in ornithology; he listed 7000 species worldwide.

The last of the early pioneers was an Englishman, Charles Darwin. His grand unifying theory of evolution brought together the disparate studies of classification, embryology, behavior, adaptation, morphology, paleontology, and distribution. The term biology, favoured by Huxley, gradually came into favour. Physiological, embryological and cell research, using the experimental method, became increasingly important.

During "the Golden Age of Natural History, 1880, 1900," zoos, museums and botanical gardens made natural history accessible to the general public. Visitors thronged to the new edifice housing the British Museum of Natural History when it opened in South Kensington, London, in 1881. Similar "cathedrals of science" became available in most major cities. There were more than 200 botanical gardens, worldwide.

The rediscovery of Mendel's Laws in 1900, Dobzhansky's use of chromosomes to divide *Drosophila* into two species, and Ernst Mayr's biological species concept led to studies of the genetics of population change.

The final chapter tells of E. O. Wilson who studied pheromones as signalling chemicals among insects. He became concerned with biodiversity, then wrote *Sociobiology*, and called for a return to the naturalist tradition, and a realization that natural history is central to the life sciences. This recommendation takes us back to where the book began, to Linnaeus and Buffon. Q.E.D.

This inexpensive paperback is primarily directed to the student and to the general public. It provides insight into the background, motivation, and achievements of the key players, all male. It should be compulsory reading for any scholar entering a biology program. Well-read naturalists will find it a useful review; they will be pleasantly surprised by the many interesting facts unearthed by Farber in his well-written presentation.

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Excavation

By Steve Roskams. 2001. Cambridge University Press, Cambridge, 311 pp. $43.50.

The science of archaeology is a little over a hundred years old. Previous to the mid-19th century, archaeology, like many natural sciences, was often restricted to trophy hunting. Today, as a result of a century of investigation and development, archaeology seeks information of all kinds. The acquisition of said information requires a broad respect for available resources and surrounding environments. *Cambridge Manuals in Archaeology* has produced its 14th installment titled *Excavation*, and is the most recent summation of the acquisition process. University of York Lecturer Steve Roskams provides a well thought out series of steps involved with archaeological investigation, covering diverse possibilities, tools, and methodology.

The fourteen chapters can be seen as covering three main sections, the first being preparation before entering the field, probably the most vital. Beginning with a short historical overview of the excavation process, Roskams highlights such basic practices as test pits, remote sensing technology, to aerial photography. Reaching farther afield, the importance of consequential activities like finance and administration, safety in the field, to archival resources must be approached before any excavation can begin.

The second section, chapters 5 to 9, encroaches on the process of excavation itself, centering on reasons and methods of record keeping including spatial and stratigraphic methodology. Drawings, photographs, grids, all help the field activity to "take place in controlled conditions, allowing full recording of the physical character and spatial disposition of the stratigraphic units in a site" (page 153). Without these measurable terms of reference, we slip back into trophy hunting.

The final section, chapters 10 to 14, covers the act of collecting and interpretations based on physical evidence such as sedimentary deposits and how to approach non-deposit finds such as buildings, bodies, and artifacts. Accomplishing any recovery or discovery, "the stuff of archaeological research"

(page 266), in a consistent manner, helps clarify the evidence with regard to broader issues and theories within archaeology. Other factors, however, must also be considered such as politics, environment, ideology, and funding, which together, fall outside of the scope of the field worker yet can hardly be dismissed in deciding where to excavate and what type of information is anticipated to be gained.

No apologies are required for the primarily British-based examples provided in *Excavation*. Those working in other geographic regions (and those working in related fields like palaeontology) can still utilize the significant resources and methodologies provided in this volume. Either as an "amateur" or "professional", Excavation is a worthy companion for any excavator.

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NEW TITLES

Zoology

†**All-weather hawk watcher's field journal.** 1999. By D. S. Heintzelman. J. L. Darling Corporation, Tacoma, Washington 50 pp., U.S. $14.95.

Awe for the tiger, love for the lamb: a chronicle of sensibility to animals. 2002. By R. Preece. UBC Press, Vancouver. 488 pp. $85.

Birding across North America: a naturalist's observations. 2002. By P. E. Keenan. Timber Press, Oregon. 260 pp., illus. U.S. $29.95.

*__Conserving bird biodiversity: general principles and their application.__ 2002. Edited by K. Norris and D. J. Pain. Cambridge University Press, New York. xiii +337 pp., illus. Cloth U.S. $100; paper U.S. $38.

†**Firefly encyclopedia of insects and spiders.** 2002. Edited by C. O'Toole. Firefly Books, Willowdale, Ontario. 240 pp., illus. $40.

*__Firefly encyclopedia of reptiles and amphibians.__ 2002. Edited by T. Halliday and K. Adler. Firefly Books, Willowdale, Ontario. 240 pp., illus. $40.

*__Fishes of Alaska.__ 2002. By C. W. Mecklenburg, T. A. Mecklenburg, and L. K. Thorsteinson. American Fisheries Society, Bethesda, Maryland. xxxvii + 1037pp + plates, illus. U.S. $129.

*__Fishes of the Gulf of Maine.__ 2002. Edited by B. B. Collette and G. Klein-MacPhee. 3rd edition. Smithsonian Institute Press, Washington. xxxiv + 748pp., illus. U. S. $75.

Game in the garden: a human history of wildlife in western Canada to 1940. 2002. By G. W. Colpitts. UBC Press, Vancouver. 216 pp., illus. $75.

*__Global register of migratory species (GROMS): database, GIS Maps, and threat analysis.__ 2002. By K. Riede. German Federal Agency for Nature Conservation. 404 pp.

*__Grassland grouse and their conservation.__ 2002. By P. A. Johnsgard. Smithsonian Institute Press, Washington (Canadian distributor Scholarly Book Services, Toronto). xiv + 151 pp., illus. $57.75.

*__Paleoimagery: the evolution of dinosaurs in art 2002.__ By. A. A. Debus and D. E. Debus. McFarland Publishers, Jefferson, North Carolina. 285 pp., illus. U.S. $49.95.

A Passion for wildlife: the history of the Canadian Wildlife Service. 2002. By J. A. Burnett. UBC Press, Vancouver. 320 pp., illus. $85.

†**Sealworms in the north Atlantic: ecology and population dynamics.** 2001. Edited by G. Desportes and G. McClelland. North Atlantic Marine Mammal Commission, Tromso, Norway. 171 pp., illus.

*__Sibley's birding basics.__ 2002. By D. A. Sibley. Knopf, New York. 154 pp., illus. U.S. $15.95; $23.95 in Canada.

Wildlife viewing in North America: a management planning handbook. 2002. Edited by M. J. Manfredo. Oregon State University Press, Corvallis. 336 pp., illus. U.S. $24.95.

†**The lost dinosaurs of Egypt.** 2002. By W. Nothdurft. Random House, Toronto. 242pp., illus. U.S. $24.95, CAD $37.95.

†**Mammals of North America.** 2002. By R. W. Kays and D. E. Wilson. Princeton University Press, Princeton. 240 pp., illus. Cloth U.S. $49.50: paper U.S. $19.95.

†**The mountain white-crowned sparrow: migration and reproduction at high altitude**. 2002. By M. L. Morton. Studies in Avian Biology No. 24. Cooper Ornithological Society, Camarillo, California. 236 pp., illus. U.S. $27.

*__North American owls: biology and natural history. 2002.__ By P. A. Johnsgard. 2nd edition. xiii + 298 pp., illus. + plates. U.S. $49.95.

Botany

Alpine plants of North America. 2002. By G. Nichols, Timber Press, Portland, Oregon. c 352 pp., illus. c U.S. $49.95.

A cactus odyssey: journeys in the wilds of Bolivia,

Peru, and Argentina. 2002. By J. D. Mauseth, R. Kiesling, and C. Ostolaza. Timber Press, Portland, Oregon. 306 pp., illus. U.S. $39.95.

Carnivorous plants of the United States and Canada. 2002. By D. Schnell. 2nd edition. Timber Press, Portland, Oregon. 468 pp., illus. U.S. $39.95.

The cycads. 2002. By L. M. Whitelock. Timber Press, Portland, Oregon. 532 pp., illus. U.S.$59.95.

†**The ecology of plants.** 2002. By J. Gurevitch, S. M. Scheiner, and G. A. Fox. Sinauer Associates, Sunderland, Massachusetts. xvi + 532 pp., illus. U.S. $89.95.

*__Flora of Glacier National Park, Montana__. 2002. By P. Lesica. Oregon State University Press, Covallis. 512 pp., illus. U.S. $32.95.

The illustrated encyclopedia of trees. 2002. By J. White. Timber Press, Portland Oregon. c800 pp., illus. cU.S. $79.95.

†**Lewis Clark's field guide to wild flowers of field and slope in the Pacific northwest.** 2002. By L. J. Clark. Edited by J. Trelawny. 3rd edition. Harbour Publishing, Madeira Park, British Columbia. 80 pp., illus. $9.95.

Portraits of Himalayan flowers. 2002. By T. Yoshida. Timber Press, Portland, Oregon. c120 pp., illus. U.S. $39.95.

*__Trees, shrubs, and vines for attracting birds.__ 2002. By R. M. DeGraaf. 2nd edition. University Press of New England, Lebanon, New Hampshire. xiii + 169 pp., illus. U.S. $19.95.

Environment

Anatomy of a conflict: identity, knowledge, and emotion in old growth forests. 2002. By T. Satterfiled. UBC Press, Vancouver. 224 pp., illus. $85.

†**The beachcomber's guide to seashore life of California.** 2002. By J. D. Sept. Harbour Publishing, Madeira Park, British Columbia. 312 pp., illus. $28.95.

†**Conservation biology.** 2002. By A. S. Pullin. Cambridge University Press, New York. xii + 345 pp., illus. Cloth U.S. $120; paper U.S. $45.

Handbook of ecological restoration, volume 1: principles of restoration. 2002. Edited by M. R. Perrow and A. J. Day. Cambridge University Press, New York. 432 pp., illus. U.S. $100: volume 2: restoration practice. 650 pp., illus. U.S. $100; 2 volume set U.S. $175.

Integrating landscape ecology into natural resource management. 2002. Edited by J. Liu and W. W. Taylor. Cambridge University Press, New York. 500 pp., illus. Cloth U.S. $120: paper U.S. $45.

Introductory ecology. 2002. By P. Cotgreave and I. Forseth. Blackwell Publishing, Oxford United Kingdom. 288 pp., illus. ,21.99.

Islands of the Arctic. 2002. By J. Dowdeswell and M. Hambrey. Cambridge University Press, New York. 320 pp., illus. U.S. $38.

†**Life, temperature, and the earth: the self-organizing biosphere.** 2002. By D. Schwartzman. Columbia University Press, New York. 241 pp., illus. U.S. $27.50.

*__The last island: a naturalist's sojourn on Triangle Island.__ 2002. By A. Watt. Harbour Publishing, Madeira Park, British Columbia. 192 pp., illus. $34.95.

Plant animal interactions. 2002. Edited by C. M. Herrera and O. Pellmyr. Blackwell Publishing, Oxford, United Kingdom. 336 pp., illus. ,35.

†**Quantitative conservation biology: theory and practice of population viability analysis.** 2002. By W. F. Morris and D. F. Doak. Sinauer Associates, Sunderland, Massachusetts. xvi + 480 pp., illus. U.S. $39.95.

Restoration of the Great Lakes: promises, practices, and performances. 2002. By M. Sproule-Jones. UBC Press, Vancouver. 160 pp., illus. $75.

†**The sacred balance: a visual celebration of our place in nature.** 2002. By D. Suzuki and A. McConnell. Greystone Books (Douglas and McIntyre), Vancouver. 151 pp., illus. $55.

†**Spatial optimization for managed ecosystems.** 2002. By J. Hof and M. Bevers. Columbia University Press, New York. xii + 257 pp., illus. Cloth U.S. $69.50; paper U.S. $32.50.

Teaching sustainability: towards curriculum greening. 2002. Edited by W. L. Filho. Peter Lang Scientific Publishers, Bern. 570 pp. Euro 69.80.

*__When the wild comes leaping up: personal encounters with nature.__ 2002. Edited by D. Suzuki. Greystone Book, Douglas and McIntyre, Vancouver. 240 pp. $32.95.

Miscellaneous

*__The backyard astronomer's guide.__ 2002. By T. Dickinson and A. Dyer. Firefly Books, Willowdale, Ontario. 320 pp., illus. $49.95.

†**The canoe: a living tradition.** 2002. Edited by J. Jennings. Firefly Books, Willowdale, Ontario, 271 pp., illus. $59.95.

The cost of climate policy. 2002. By M. Jaccard, J. Nyboer, and b. Sadownik. UBC Press, Vancouver. 288 pp., illus. Cloth $85; paper $29.95.

*__The emperor of nature: Charles-Lucien Bonaparte and his world.__ 2000. By P. T. Stroud. University of Pennsylvania Press, Philadelphia. 371 pp. U.S. $34.95.

†**The hydrogen economy.** 2002. By J. Rifkin. Tarcher/Putnam, New York. 283 pp., U.S. $24.95.

***John Keast Lord: materials for a life.** 2002. By D. Baker. Backhuys Publishers, Leiden, Netherlands. 78 pp., illus. Euro 22.

***The power of place: Charles Darwin, the origin and after – the years of fame.** 2002. By J. Browne. Alfred A Knopf, New York. 624 pp., illus. U.S. $37.50.

Books for Young Naturalists

Salmon. 2002. By D. Hodge. Kids Can Press, Tonawanda, New York. 32 pp., illus. U.S. $10.95.

Seashells by the seashore. 2002. By M. Berkes. Dawn, Nevada City, California. 32 pp., illus. U.S. $8.95.

*Assigned for review
†Available for review

News and Comment

Errata The Canadian Field-Naturalist 115(4)

Baird, R. W. 2001. Status of Killer Whales, *Orcinus orca*, in Canada. Canadian Field-Naturalist 115(4): 676–701.

Figure 4. This figure should have included two photographs, one (left) showing the dorsal fin of resident Killer Whales, and one (right) showing the dorsal fin of transient Killer Whales. Only one photograph, of transient Killer Whales, is included in the Figure. Resident Killer Whales are shown in Figure 3, on opposite page.

Errata The Canadian Field-Naturalist 116(1)

Inside front cover, bottom, caption for front cover: "Wood Bison, *Bison bison bison*" should read "Bison, *Bison bison*". The population originally native to Wood Buffalo Park was designated Wood Bison as *Bison bison athabascae* Rhodes, 1898, Proceedings of the Academy of Natural Science, Philadelphia 49: 498, but the taxomonic distictiveness has long been debated. If regarded as distinct, the Plains Bison is *Bison bison bison* (Linnaeus, 1758) [See RENEW: National Recovery Plan Number 21: The Wood Bison, *Bison bison athabascae*, October 2001, 50 pages, Recovery Secretariat c/o Canadian Wildlife Service, Ottawa, K1A 0H3, noted in News and Comment in The Canadian Field Naturalist 116(1): 178]. The date of the cover photograph 116(1) was 7 July 1951, and the location was about 62 miles from Fort Smith on the road to Pine Lake. These Bison were probably hybrids *Bison bison bison* X *athabascae*, or simply *Bison bison*. The Plains Bison had been introduced in the years 1925 to 1928 so they had more than 20 years to interbreed by 1951. [W. A. Fuller 13 December 2002].

On page 146, left column, line 46, 1923 should be 1823, and the reference is to Sabine, Zoological Appendix V in Franklin 1823.

Recovery: An Endangered Species Newsletter (20) March 2002

Published by the Canadian Wildlife Service this issue contains: RECOVERY HIGHLIGHTS: Strategy drafted — Saving the martens — New Law [Newfoundland and Labrador]; PROFILE: Team's efforts paying off [David Wylynko]; SPECIAL REPORT: Kids, space, and species; NEWS BITES: Reintroducing snails — Recovering the copper redhorse — Orchid research underway — Updates: COSEWIC, RENEW — Deerberry recovery — Plan drafted [whooping crane] — Coastal flora at risk — FIELD NOTES: Monitoring trout [Ed Snucins] — The importance of animal behaviour [Abby Schwartz] — Tracking toads [David Green]; ANNOUNCEMENTS: New publications — Upcoming events — Site seeing; FEATURED SPECIES: Conserving a rare plant [Alain Gouge]. Contact: Recovery, Canadian Wildlife Service, Environment Canada, Ottawa, Ontario K1A 0H3. Web site: www.cws-scf.ec.gc/recovery/archive.htmla

Froglog: Newsletter of the Declining Amphibian Populations Task Force (50)

Number 50, April 2002, Celebrating Froglog's Golden Jubilee! CONTENTS: A Message from DAPTF's Co-Founder (David Wake) — DAPTF Seed Grants (Tim Halliday, DAPTF International Director) — Breeding Pond Survey in Hungary: an Example of Successful Cooperation (Tibor Kovacs & Miklos Papp) — Green and Golden Bell Frogs on Kooragang Island [Australia] (Robert Browne Chairperson, Friends of the Hunter Bell Frogs) — Meeting in the Basque Country (Tim Halliday) — California-Nevada Working Group Meeting Report (David Bradford, Working Group Chair) — A Comparative Study of the Amphibian Community at Three Sites in Penang State, Malaysia — Froglog Shorts — Publications of Interest.

Froglog is the bi-monthly newsletter of the Declining Amphibian Populations Task Force of The World Conservation Union (IUCN)/Species Survival Commission (SSC) and is supported by The Open University, The World Congress of Herpetology, and Harvard University. The newsletter is Edited by John W. Wilkinson, Department of Biological Sciences, The Open University, Walton Hall, Milton Keynes, MK7 6AA, United Kingdom; e-mail: daptf@open.ac.uk. Funding for *Froglog* is underwritten by the Detroit Zoological Institute, P. O. Box 39, Michigan 48068-0039, USA.

National Recovery Plan (22): Piping Plover March 2002

The National Recovery Plan for the Piping Plover (*Charadrius melodus*) by the Prairie and Atlantic Piping Plover Recovery teams (J. P. Goossen, D. L. Amirault, J. Arndt, R. Bjorge, S. Boates, J. Brazil, S. Brechtel, R. Chiasson, G. N. Corbett, R. Curley, M. Elderkin, S. P. Flemming, W. Harris, L. Heyens, D. Hjertaas, M. Huot, B. Johnson, R. Jones, W. Koonz, P. Laporte, D. McAskill, R. I. G. Morrison, S. Richard, F. Shaffer, C. Stewart, L. Swanson, and E. Wiltse) is now available as Number 22, 47 pages, from Recovery Secretariat c/o Canadian Wildlife Service, Environment Canada, Ottawa, Ontario K1A OH3, Canada; e-mail RENEW-RESCAPE@ec.gc.ca; See also RECOVERY web site:
English:
http://www.speciesatrisk.gc.ca/sar/efforts/index.htm
Francais:
http://www.especesenperil.gc.ca/eep/efforts/index.htm

Point Pelee Natural History News 2(1) Spring 2002

This newsletter for Point Pelee National Park, Ontario, is edited by Alan Wormington (e-mail: wormington@juno.com). Editorial Assistants are M. Lea Martell and Matthew J. Smith. The web site is www.wincom.net/~fopp/Natural_History_News.htm
ARTICLES: The Point Pelee Lesser Nighthawk: A Unique Record for Ontario and Canada (Alan Wormington) — Noteworthy bird records: December 2001 to February 2002 (Alan Wormington) — "Saskatchewan" Horned Lark: New to Ontario (Alan Wormington) — Point Pelee Christmas Bird Count: December 17, 2001 (Sarah Rupert) — Point Pelee Butterflies: Annual Summary for 2001 (Alan Wormington) — Upcoming EVENTS AND OUTINGS.
Subscription rates are Canada: CAN $15 (one year) or $30 (two years); International: US $15 (one year) or $30 (two years). Send payment (and e-mail address, optional) to The Friends of Point Pelee, 1118 Point Pelee Drive, Leamington, Ontario N8H 3V4 Canada. Issues are mailed in March, June, September, and December, and back issues are available for $15 per Volume/ $5 per issue (postage paid).

Marine Turtle Newsletter (96)

The April 2002 issue, 40 pages, contains: EDITORIAL: Hype (Nicholas Mrosovsky) — ARTICLES: Marine turtle nesting in Kuriat Islands, Tunisia, 2000 — Observations on the first day dispersal of neonatal Hawksbill Turtles (*Eretmochelys imbricata*) — In-water survey of Hawksbill Turtles at Kuna Yala, Panama — Evidence for Leatherback Sea Turtle (*Dermochelys coriacea*) nesting in Arraial do Cabo, State of Rio de Janeiro, and a review of occasional Leatherback nests in Brazil — Sea Turtles nesting in the South Bay of Great Nicobar Island — Marine turtles nesting at St. Martin's Island, Bangladesh. NOTES: A record of the Leatherback Sea Turtle (*Dermochelys coriacea*) from Cambodia — LETTER TO THE EDITORS: Viewpoint: Sea turtle management in Bangladesh — ANNOUNCEMENTS — NEWS & LEGAL BRIEFS — RECENT PUBLICATIONS.

The Marine Turtle Newsletter is edited by Brendan J. Godley and Annette C. Broderick, Marine Turtle Research Group, School of Biological Sciences, University of Wales, Swansea, SA2 8PP Wales, United Kingdom; e-mail MTN@swan.ac.uk; Fax +44 1792 295447. Subscriptions to the MTN and donations towards the production of MTN and its Spanish edition NTM [Noticiero de Tortugas Marinas] should be sent to Marine Turtle Newsletter c/o Chelonian Research Foundation, 168 Goodrich Street, Lunenburg, Massachusetts 01462 USA; e-mail RhodinCRF @aol.com; fax + 1 978 582 6279. MTN website is: <http://www.seaturtle.org/mtn/>

The Boreal Dip Net: Newsletter of the Canadian Amphibian and Reptile Conservation Network 6(2) April 2002

Contents: Editor's note [Kerrie Serben]; Charlottetown West: Revisiting the PEI Meeting at Eastern Ontario Biodiversity Museum 27 January 2002 [Aleta Karstad] — Projects en herpetologie au Quebec [Jacques Jutras et collaborateurs] — Ontario snake and lizard advisory group formed [David Seburn] — Herpwatch [Aquatics, Banff National Park Warden Office] — Considerations of the inadequacy of wildlife reserve sizes in Ontario for the conservation of reptiles and amphibians (Shane R. de Solla] — Habitat use and movement patterns of Northern Alligator Lizards and Western Skinks in southeastern British Columbia [Pamela Rutherford and Patrick Gregory] — Don't be caught out standing in a pond the spring! [FrogWatch, NatureWatch Program, joint venture of Canadian Nature Federation and the Ecological Monitoring and Assessment Network Coordinating Office, Environment Canada] — Field notes: Northern Dusky Salamander [Glenn Barrett and Kim Smith] — Message in a bottle: A new beer launched in support of species at risk [Andree Gendron] — The new atlas of the reptiles and amphibians of Vermont is now available [James S. Andrews] — Herpetological activities in eastern Canada in 2002: monitoring-conservation-education-research [Martin Ouellet].

For information on membership in the Canadian Amphibian and Reptile conservation society ($10 students, $16 non-students] contact Bruce Pauli, Canadian Wildlife Service, National Wildlife Research Centre, 100 Gamelin Boulevard, Hull, Quebec K1A 0H3. Web site: http://www.carcnet.ca/

Alberta Wildlife Status Reports numbers 40, 41, 42, 43, 44

The Fisheries and Wildlife Management Division of the Alberta Natural Resource Status and Assessment Branch, Alberta Environmental Protection, has released new Wildlife Status Reports. The Series Editors for reports 40 to 44 are Sherry Frazer and Robin Gutsell and the illustrations for all five are by Brian Huffman. For a listing earlier numbers in the series, see *The Canadian Field-Naturalist* 112(1): 169 for 1-11; 113(2): 311 for 12-17; 113(4): 686 for 18-21; 114(1): 151 for 22-25; 115(2): 390 for 26-31; 115(3): 000 for 32-36, 116(1): 000-000. Recent reports issued in 2002 are 40, 41, 42 and 44, dated March 2002: 43 is dated May 2002):

40. Status of the Banff Springs Snail (*Physella johnsoni*) in Alberta, by Dwayne A. W. Lepitzki. 29 pages.
41. Status of the Shortjaw Cisco (*Coregonus zenithicus*) in Alberta, by Mark Steinhilber. 23 pages.
42. Status of the Prairie Falcon (*Falcon mexicanus*) in Alberta, by Dale Paton. 28 pages.
43. Status of the American Badger (*Taxidea taxus*) in Alberta, by Dave Scobie. 17 pages.
44. Status of the Yuca Moth (*Tegeticula yuccasella*) in Alberta, by Donna Hurlburt. 21 pages.

For copies contact the Information Centre - Publications Alberta Environment/Alberta Sustainable Resource Development, Fish and Wildlife Division, Main Floor, Great West Life Building, 9920 - 108 Street, Edmonton, Alberta T5K 2M4 Canada [telephone: (780) 422-2079], OR Information Service Alberta Environment/Sustainable Resource Development, #100, 3115 - 12 Street NE, Calgary, Alberta T2E 7J2, Canada [telephone: (403) 297-3362]; web site: http://www3.gov.ab.ca/srd/fw/status/index.html.

Editor's Report for Volume 115 (2001)

Mailing dates for issues in volume 115 were: (1) 10 July 2001; (2) 14 December 2001; (3) 30 April 2002; (4) 9 August 2002. A summary of membership and subscriber totals 2001 is given in Table 1. The number of articles and notes in volume 115 is summarized in Table 2 by topic; totals for Book Reviews and New Titles are given in Table 3, and the distribution of content by page totals per issue in Table 4. Council continued making 80% of the annual interest from the Manning Fund and other capital available to *The Canadian Field-Naturalist* to offset the publication cost of northern papers where authors and institutional contributions were insufficient to cover page charges.

St. Joseph Print Group, Ottawa (now including the former M.O.M. Printers) set and printed the journal. Special thanks are due Emile Holst, and to Cecilia Chow and the pre-press staff for galleys and corrections as well as those in the printing and bindary sections whose efforts make each issue possible. Wanda J. Cook proof-read the galleys and Bill Cody as Business Manager handled all reprint requests and bills and oversaw and proofed the compilation of the Index prepared by Leslie Durocher. Wilson Eedy continued as Book-Review Editor (his report follows).

Manuscripts (excluding book reviews, notices, and reports) submitted to *The Canadian Field-Naturalist* totalled 125 in 2001, down 29 from 154 in 2000. The following reviewed papers submitted in late in 2000 and in 2001: Associate Editors: R. Anderson, Canadian Museum of Nature (3); W. B. Ballard, Texas Tech University, Lubbock (10); C. D. Bird, Erskine, Alberta (26); B. W. Coad, Canadian Museum of Nature (9); R. Campbell, Ottawa, (6); P. M. Catling, Agriculture and Agri-food Canada, Ottawa (14); A. J. Erskine, Canadian Wildlife Service, Sackville,

TABLE 1. The 2001 circulation of The Canadian Field-Naturalist (2000 in parenthesis). Membership totals from Annual Report of the Ottawa Field-Naturalists' Club, January 2002; subscription totals compiled by W. J. Cody. Forty percent of membership dues and 100% of subscriptions go to publication of *The Canadian Field-Naturalist*. Members vote on Club affairs, subscribers and institutions do not.

	Canada		USA		Other		Totals	
Memberships								
Family & individual	941	(910)	30	(32)	7	(6)	978	(948)
Subscriptions								
Individuals	189	(184)	63	(61)	3	(6)	255	(251)
Institutions	174	(178)	262	(255)	38	(38)	474	(471)
Totals	363	(362)	325	(316)	41	(44)	729	(722)
TOTALS	1304	(1272)	355	(348)	48	(50)	1707	(1670)

Note: 22 countries are included under "Other" (outside Canada and United States): Austria, Belgium, Brazil, Denmark (2), United Kingdom (9: including 1 to Scotland), Finland (2), France (3: including 1 to St. Pierre & Miquelon), Germany (2), Iceland, Ireland, Japan, Mexico, Netherlands (3), New Zealand, Norway (4), Poland, Russia, South Africa, Spain (3), Sweden (2), Switzerland (2), Trinidad and Tobago.

TABLE 2. Number of articles and notes published in *The Canadian Field-Naturalist* Volume 115 (2001) by major field of study.

Subject	Articles	Notes	Total
Mammals	19	8	27
Birds	12	9	21
Amphibians + reptiles	3	3	6
Fish	15	1	16
Invertebrates	5	0	5
Plants	14	4	18
Tributes	2	0	2
Totals	70	25	95

New Brunswick (31); W. O. Pruitt, Jr., University of Manitoba, Winnipeg (55). Other reviewers: R. Alvo, Gatineau, Quebec; R. Anderson, Seattle Aquarium, Washington; M. N. Arai, Pacific Biological Station, Nanaimo, British Columbia; A. Bailey, University of Alberta, Edmonton, Alberta; W. M. R. Barclay, University of Calgary, Alberta (2); W. Berg, Minnesota Department of Natural Resources, Grand Rapids; J. R. Bider, Ecomuseum, Ste-Anne-de-Bellevue, Quebec (4); M. Blouw, University of Northern BC, Prince George; J. Bowman, Carleton University, Ottawa, Ontario; C. Braun, Colorado State University, Fort Collins (2); S. Breck, Colorado State University, Fort Collins; A. Brinckmann-Voss, Sooke, British Columbia; I. Brodo, Canadian Museum of Nature, Ottawa, Ontario; R. J. Brooks, University of Guelph, Ontario (3); T. Brunjes, Texas Technical University, Lubbock, Texas; M. Cadman, Canadian Wildlife Service, Guelph, Ontario; D. Colwell, Canada Agriculture and Agri-Food, Lethbridge; L. Carbyn, CWS, Edmonton, Alberta (4); J. G. Casey, Narragansett, Rhode Island; J. Cayouette, Agriculture and Agri-food Canada, Ottawa; P. Cochran, Saint Mary's University, Winona, Minnesota; W. J. Cody, Agriculture and Agri-food Canada, Ottawa, Ontario (8); J. A. Cook, Museum, University of Alaska, Fairbanks; V. Crichton, Manitoba Natural Resources, Winnipeg; E. J. Crossman, Royal Ontario Museum, Toronto (4); D. Cuddy, OMNR, Kemptville, Ontario; S. J. Darbyshire, Agriculture and Agri-food Canada, Ottawa (2); R. W. Davies, University of Calgary, Alberta; M. W. Demarchi, LGL Limited, Sidney, British Columbia; K. De Smet, Manitoba Conservation, Meleta; A. Dextrase, Ontario Ministry of Natural Resources, Peterborough; G. W. Douglas, BC Data Centre, Victoria (2); J. Dubois, Manitoba Natural Resources, Winnipeg (3); B. A. Ford, University of Manitoba, Winnipeg; R. Fortin,

TABLE 3. Number of reviews and new titles published in Book Review section of *The Canadian Field-Naturalist* Volume 114 by topic.

	Reviews	New Titles
Zoology	16	112
Botany	7	24
Environment	11	61
Miscellaneous	3	18
Young Naturalists	–	56
Totals	37	271

TABLE 4. Number of pages per section published in *The Canadian Field-Naturalist* Volume 115 (2001) by issue.

	(1)	(2)	(3)	(4)	Total
Articles	167	142	104	159	572
Notes	17	16	18	0	51
Book Reviews*	12	9	14	26	61
Tributes		24	3		27
CFN/OFNC Reports**		3	7	4	14
News and Comment	2	2	2	2	8
Index				35	35
OFNC Publications				1	1
Advice to Contributors				1	1
Totals	198	196	148	228	770

*Total pages for book review section include both reviews and new titles listings.

**Includes CFN Editors reports (issue 2), OFNC Annual Business Meeting (3) and OFNC Awards (4).

Université du Québec à Montréal, Québec (2); B. Freedman, Dalhousie University, Halifax, Nova Scotia; A. J. Gaston, Canadian Wildlife Service, Gatineau, Quebec (2); L. Gillespie, Canadian Museum of Nature, Ottawa; P. T. Gregory, University of Victoria, British Columbia (2); I. Hatter, British Columbia Ministry of Environment, Lands and Parks, Victoria; D. Heard, British Columbia Ministry of Environment, Lands and Parks, Prince George; B. J. Hearn, Natural Resources Canada, Corner Brook, Newfoundland; D. Helm, University of Alaska, Palmer; J. D. Henry, Klune National Park, Yukon; L. V. Hills, Cochrane, Alberta; E. Holm, Royal Ontario Museum, Toronto; G. Holroyd, Canadian Wildlife Service, Edmonton, New Brunswick; C. S. Houston, Saskatoon, Saskatchewan (3); P. Hurley, Department of Fisheries and Oceans, Darmouth, Nova Scotia; T. C. Hutchinson, Trent University, Peterbourgh, Ontario; P. James, Royal Saskatchewan Museum, Regina; R. James, Sutherland, Ontario (3); H. M. Jahns, Heinrich Heine Universitat, Dusseldorf, Gemany; C. E. Kay, Utah State University, Logan; P. Keddy, Carleton Place, Ontario (3); M. R. Lein, University of Calgary, Calgary; L. E. Licht, York University, North York; J. W. Lish, Oklahoma State University, Stillwater; R. MacCulloch, Royal Ontario Museum, Toronto; C. Machtans, Candian Wildlife Service, Yellowknife, Northwest Territories; J. Madill, Canadian Museum of Nature, Ottawa; F. F. Mallory, Laurentian University, Sudbury (2); A. Martel, Canadian Museum of Nature, Ottawa (2); J. Mather, University of Lethbridge, Alberta; T. O. Matson, Cleveland Museum of Natural History, Ohio; J. Maunder, Newfoundland Museum, St. John's (2); D. F. McAlpine, New Brunswick Museum, Saint John (4); R. McCaffrey, Texas Techical Unversity, Lubbock (2); B. McCune, Oregon State University, Corvalis; W. B. McGillivray, Alberta Provincial Museum, Edmonton (3); L. David Mech, Raptor Center, University of Minnesota, St. Paul (2); J. S. Millar, University of Western Ontario, London; J. Metcalfe-Smith, National Water Research Institute, Burlington, Ontario; G. Morrison, Canadian Wildlife Service, Gatineu, Quebec; K. Murphy, Yellowstone Park, Wyoming; D. W. Nagorsen, Victoria, British Columbia (7); R. W. Nero, Manitoba Natural Resources, Winnipeg, Manitoba; W. A. C. Nixon, Canadian Wildlife Service, Yukon; L. Noel, LGL Alsaka Research Associates,

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FRANCIS R. COOK
Editor

Book-review Editor's Report for Volume 115 (2001)

This has been a very eventful year for your book-review editor and I want to make sure everyone knows where I am. After 28 years in one location, I have moved my address. From one remote, dead-end, ANSI and ESA area to a little less remote but still green-belt location, about 9 ha on the edge of the Mad River, just southwest of Barrie. Reviewers will have to forgive any tardiness due to files still in boxes, my still working in Africa, and major renovations at home. These latter include one huge frog pond and bird habitat creation in the front lawn.

For those who want to find me: RR# 1, Glencairn, Ontario L0M 1K0; e-mail terfa@geoniger.com.

Book reviewing for the Canadian Field-Naturalist in 2001 was a little slower than usual. Although we received a large number of complimentary titles from publishers (102), only 65 were sent to reviewers and 56 reviews published in the journal. The number of new titles listed, 261, was also low, but partly due to only listings in 3 issues. This means we have a large number of books still available for reviewers and welcome contacts from both old or new reviewers. Just let me know the topics that you are interested in and I will send suggestions that you can pick from. You can also suggest titles from those listed as available in New Titles or even suggest relevant new books which I have missed. Most publishers will provide complimentary copies on request. The book becomes the property of the reviewer and the review is published in our journal.

WILSON EEDY
Book-review Editor

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Cover: A mat of the Eastern Mosquito Fern, *Azolla caroliniana,* stranded on the mud substrate with other aquatic vegetation and fallen leaves at Brown's Inlet, Ottawa, after the draw-down of water in the Rideau Canal, October 1997. Photographed by S. J. Darbyshine (see pages 441–445).

The Canadian Field-Naturalist

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Double-crested Cormorants, *Phalacrocorax auritus*, at Inland Lakes North of Lake Huron, Ontario

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Alvo, Robert, Chris Blomme, and D. Vaughn Weseloh. 2002. Double-crested Cormorants, *Phalacrocorax auritus*, at inland lakes north of Lake Huron, Ontario. Canadian Field-Naturalist 116(3): 359–365.

Three long-term data sets were used to document the use of inland lakes north of Lake Huron by Double-crested Cormorants (*Phalacrocorax auritus*). After the first reported sighting in the Sudbury Region in 1971, the species was observed regularly from 1979 onwards. It was not a summer resident in the area until 1987 and noteworthy multiple numbers were not reported until 1991. These non-breeding birds may have originated as spring migratory "overshoots" from Georgian Bay, Lake Huron; birds observed in the autumn were probably migratory stragglers from farther north. It is unlikely that they came from the east or west because present day colonies there were not active yet. The only two known breeding sites in the region are at Kelley Lake and Lake Wanapitei. Breeding at Kelley Lake began in 1996; in Lake Wanapitei, breeding was confirmed in 1999, but may have begun earlier. These sightings represent the earliest movements of cormorants away from the Great Lakes since their resurgence there, and these birds may establish breeding sites at small inland lakes in this area. These movements into the Sudbury Region are not to be confused with daily foraging flights to inland lakes which are seen within several kilometres of the Great Lakes. Further research is required to study what impact cormorants might have on inland lake ecosystems and to determine whether cormorants are seen with increased frequency elsewhere in the Great Lakes watershed.

Key Words: Double-crested Cormorant, *Phalacrocorax auritus*, colony, Sudbury, North Bay, Manitoulin, Ontario, expansion.

The Double-crested Cormorant (*Phalacrocorax auritus*) has been undergoing a continent-wide population expansion since the mid- to late-1970s (Weseloh et al. 1979; Scharf and Shugart 1981; Hatch 1984). Nowhere has this been more dramatic than on the Great Lakes (Weseloh et al. 1995). This has caused widespread concern as cormorants are perceived as having severe negative impacts on at least three components of the ecosystem: (1) fisheries (e.g., Smallmouth Bass, *Micropterus dolomieu*, in eastern Lake Ontario: Schneider et al. 1998); (2) vegetation (e.g., islands in the St. Lawrence River: Alvo 1996; and western Lake Erie: DVW, personal observations); and (3) other colonial species with which cormorants nest (e.g., Great Blue Herons, *Ardea herodias*, and Black-crowned Night-Herons, *Nycticorax nycticorax*: Wires and Cuthbert 1999*; Jarvie et al. 1997).

In the early 1900s, the Double-crested Cormorant bred in the Gulf of St. Lawrence and on lakes in the prairie provinces, and was "a rather uncommon though perhaps regular migrant on the Great Lakes" (Taverner 1919). The breeding population on the Great Lakes increased slowly from the first known colonization in 1913–1920 to around 900 pairs by the 1950s. However, reproductive failure caused by DDE-induced eggshell thinning and subsequent egg breakage reduced the population to less than 150 pairs by 1972; the species abandoned all breeding sites in Lake Michigan, Lake Superior, and the main body of Lake Huron (Postupalsky 1978*). Since then, the cormorant population has increased dramatically, probably due to a combination of factors: reduced human persecution, declining levels of organochlorine contaminants (Ryckman et al. 1998), and an abundance of forage-base fish, notably Alewife (*Alosa pseud oharengus*) and Rainbow Smelt (*Osmerus mordax*) (Christie 1974). This abundance of forage-base fish followed the dramatic decline of Great Lakes stocks of predatory fish between the 1940s and 1960s, which has been attributed to predation by Sea Lampreys (*Petromyzon marinus*) and human over-exploitation (Christie 1974; Christie et al. 1987).

*See Documents Cited section

From 1973 to 1993, the breeding cormorant population on the Great Lakes increased over 300-fold to more than 38 000 pairs (Weseloh and Collier 1995). In 1991, about 40% of the Canadian Great Lakes cormorant population bred in Lake Huron, where the nesting population grew from nine colonies with 335 nests in 1980 to 41 colonies with 6018 nests in 1989, representing a mean annual growth rate of 38% (Blokpoel and Tessier 1997). In 2000, cormorants bred on numerous islands in Lake Huron, with most of the population concentrated along its north shore; i.e., off Manitoulin Island, in the North Channel, and along the north and east coasts of Georgian Bay (Blokpoel and Tessier 1997; D. V. Weseloh, unpublished data).

In Ontario and the U.S. states bordering the Great Lakes, breeding cormorants are most numerous along the Great Lakes shoreline and offshore islands. In these situations where cormorant activity seems confined to the Great Lakes proper, a feeling of having "isolated" any perceived cormorant problem from inland habitats often seems to prevail. However, great fear has often been expressed by wildlife managers that, if cormorants began using small inland lakes, the perceived problems would escalate. This subject has received little published scrutiny. Here we use three long-term data sets to document the initial stages of expansion into small inland lakes north of Georgian Bay, Lake Huron.

Methods

This study is based on three data sets: (A), (B), and (C).

(A) As part of a long-term loon study in the region of Sudbury, Ontario (Alvo et al. 1988), RA recorded all observations of aquatic birds. Observations were made annually from 1982 to 1990, in 1993, and from 1996 to 1998. In 1982, 84 lakes were visited from mid-June to late-August. In 1996 the same 84 lakes, plus 10 added in 1988 (see below), were visited from mid-June to late October. In the other years a subset of 30 lakes (the same 30 every year) was visited from late August to mid-September. In addition, in 1988, 10 lakes were added to the study, and they were surveyed from late August to mid-September in succeeding years with observations as described above. Usually only one visit per lake was made each year, but in 1982 and 1996 two visits per year were made. Thus, the number of lakes surveyed per year was as follows: 1982: 84; 1983–1987: 30; 1988–1990 and 1993: 40; 1996: 94; 1997–1998: 40. In total, 94 lakes were visited 746 times. They were located 35–135 km from the 381-m tall Inco smelter "superstack" near Sudbury. This study region, henceforth referred to as the "outlying Sudbury region", forms a large quadrilateral block, with its axis in a north-south direction, north of Georgian Bay (Figure 1).

(B) The second data set was compiled by CB, who searched for cormorant observations in the Sudbury Region in the *Manitoulin and Sudbury District Bird Reports* [the monthly report of birders who subsequently formed the Sudbury Ornithology Society — SOS] for the 1972–1999 period (editors John Lemon and John Nicholson). These reports summarized members' observations made during each month. In 1972–1976, all monthly reports were based on the observations of at least six observers. In 1977–1998, monthly reports were based on observations of an average of 10.4 observers. For each bird species, historical or first time sightings were noted, as were the earliest spring and latest autumn observations and the range of summer residency dates. The geographical area covered includes a roughly 40 km radius around the city of Sudbury; i.e., an area overlapping by about 40% with A (Figure 1). Observations by CB for the same 28-year period, and reports obtained during conversations with local birders, were also included in this data set. For simplicity, this data set is referred to as the "SOS" data.

(C) The third data set comprises 97 counts of cormorants on Kelley Lake (339 ha), located 3 km southwest of the city (Sudbury) core. The counts were made by CB from 1972 to 1999 at various times during the breeding seasons (Figure 1). Kelley Lake is noted for its waterfowl migrants in the spring and fall, as well as for its summer resident waterfowl populations (Whitelaw 1989*).

Results

(A) During the 1982–1990 period, no cormorants were observed on any of the loon study lakes after 438 visits to 94 lakes (Table 1). In contrast, 1–2 individuals were observed on eight occasions from 1993 to 1998 on seven of the 94 study lakes visited 308 times (Table 1). Most sightings involved single birds on the lakes and occurred in September. The distance between each of the seven lakes involved and the nearest portion of Georgian Bay varied from 7 to 160 km. The lakes closest to Georgian Bay were in Killarney Provincial Park.

(B) The first cormorant sighting reported to the SOS in the Sudbury Region was a single bird on Lake Panache on 22 May 1971 seen by Ross Lowe (Nicholson 1974*). No other cormorant sightings were reported to the SOS until 1979. Eight sightings (1–3 birds per sighting) were reported from the Sudbury Region in 1979–1985 (Table 2). None were reported in 1986–1988 except at Kelley Lake (Figure 1 and see below). From 1989 to 1999, however, there were 17 sightings with up to 47 birds per sighting, excluding those reported from Kelley Lake. All these observations were made within 30 km of Sudbury (Figure 1, Table 2).

Unconfirmed reports (not in the SOS files) of

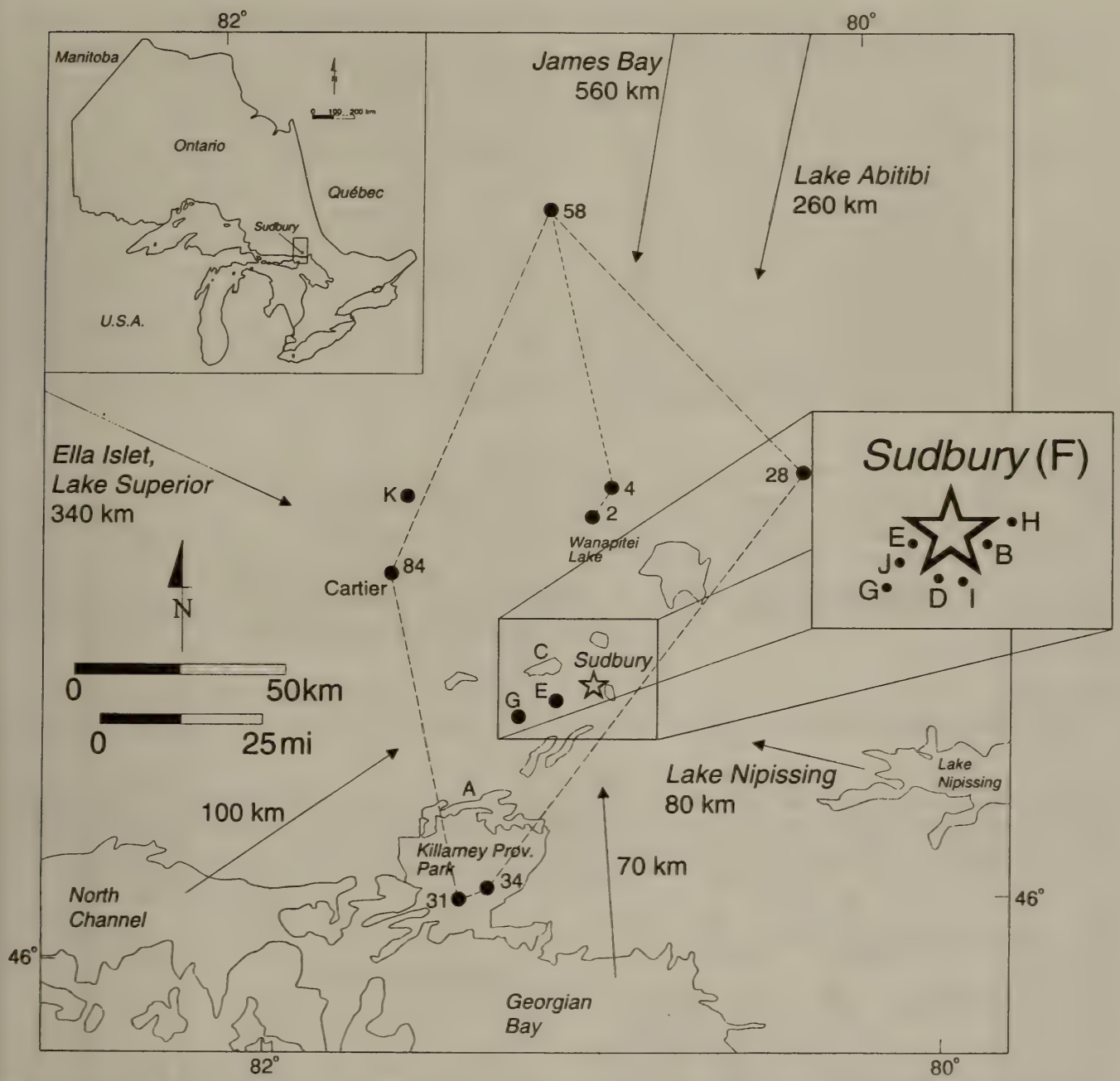

FIGURE 1. Map showing the area north of Lake Huron (Georgian Bay), including: (a) numbered sites from the "outlying Sudbury region" (delimited by dashes) (see Table 1 and Alvo (1985*)); (b) lettered sites where SOS observations were reported (see Table 2), (c): blow-up of the immediate area of the City of Sudbury; (d) location of Wanapitei Lake, (e) the direction and distance of the nearest cormorant colony in each major direction, and (f) inset showing study area in Ontario.

cormorants observed on shoals and islands on the southeast corner of Wanapitei Lake since 1995 were made, and up to seven individuals were seen in flight over the lake (B. Olivier, personal communication). This is by far the largest lake in the Sudbury region (13 131 ha). In an attempt to verify these observations and determine whether breeding had occurred, a low-level flight by float plane was made on 25 October 1999 over the shoals and islands. Definitive remains of at least 14 cormorant nests were observed on one of the small unnamed islands (46°43′20″N, 80°40′50″W) (DVW and L. Shutt, Canadian Wildlife Service, personal observation).

(C) Neither CB nor other SOS members noted any summer resident cormorants (i.e., cormorants that appeared to have taken up extended daily residence) on Kelley Lake from 1972 to 1986, despite an annual average of 14.5 visits by CB alone (with a minimum of two visits in 1977 and a maximum of 29 in 1980). The first summer resident cormorants were reported on Kelley Lake in 1987 (Figures 1 and 2). From 1987 to 1999, the reported cormorant numbers on Kelley Lake fluctuated from 1 to 103; birds were reported there in all months from 8 April to 4 October. Breeding began there in 1996 with two nests containing five eggs (12 June) and was the first known nesting for the Sudbury

TABLE 1. Summary of (A) RA's observations of Double-crested Cormorants on inland lakes north of Georgian Bay, 1982–1998.

Date	Lake No.[1]	Lake Size (ha)	# Cormorants
1982–1990	No cormorants observed.		
13 September 1993	4	22.0	1
16 September 1993	58	5.3	1
19 June 1996	31	33.6	1
03 August 1996	34	Ca. 200	2
14 September 1996	28	11.4	1
14 September 1997	2	7.1	1
19 September 1997	84	14.3	1
05 September 1998	4	22.0	1

[1]Lake numbers correspond to those used by Alvo (1985*).

Region (Peck 1997*). In 1997, six nests and 15 young were counted on 29 July (C. Blomme, unpublished data). The colony was active in both 1998 and 1999, when young were observed. Definitive remains of 26 nests and one dead juvenile were counted on 18 November 1999. Nesting occurred in 2000 through 2002 inclusive.

Discussion

With one exception, cormorants were not reported within 35–40 km of Sudbury until 1979. Birds were not "seasonal residents" in this region until 1987, and the first breeding apparently did not occur there until 1996. In the outlying Sudbury region, no cormorants were observed during the nine-year period 1982–1990, but they were observed regularly in small numbers, primarily in the autumn, from 1993 onwards.

In the late 1970s to mid-1980s, when only one to three cormorants per year were being reported in the

TABLE 2. List of all observations of Double-crested Cormorants on inland lakes near Sudbury as reported by the Sudbury Ornithological Society from 1972 to 1999. Only the first sighting is listed for Kelley Lake. Observations at sites other than lakes represent birds in flight. Letters in parentheses refer to lakes mapped in Figure 1.

Date	Site	Size (ha)	# birds
22 May 1971	Panache Lake (A)	8959	1
1972-1978	No cormorants observed.		
24 June 1979	Panache Lake	8959	1
06 May 1980	Bethel Lake (B)	31	1
29 April 1981	Whitewater Lake (C)	944	3
24 May 1981	Kelley Lake (D)	339	1
28 April 1982	Whitewater Lake	944	1
29 May 1982	Whitewater Lake	944	1
15 May 1985	Copper Cliff (town) (E)	—	3
15 June 1985	Sudbury (city) (F)	—	1
26 April 1989	Lively (town) (G)	—	2
27 August 1990	Ramsey Lake (H)	795	3
31 August 1990	Bethel Lake	31	1
12 May 1991	Robinson Lake (I)	33	1
29 May 1991	Meatbird Lake (J)	79	7
07 September 1991	Laurentian University	—	20
01 September 1992	Bethel Lake	31	1
01 October 1992	Bethel Lake	31	1
26 April 1995	Whitewater Lake	944	2
22 July 1995	Lively (town)	—	20
07 August 1995	Creighton Mine, Lively (town)	—	1
17 September 1995	Halfway Lake (K)	247	8
01 September 1997	Ramsey Lake	795	6
22 April 1998	Whitewater Lake	944	1
31 May 1998	Robinson Lake	33	6
21 April 1999	Whitewater Lake	944	7
24 September 1999	Meatbird Lake	79	47

Sudbury Region, the nearest known breeding colonies were in northern Georgian Bay and the North Channel of Lake Huron, 70–100 km away (Figure 1). Colonies there were growing rapidly. In northern Georgian Bay nest numbers (= pairs of breeders) increased from 64 to 342 in 1980–1985 — an annual growth rate of 40% (DVW unpublished data). Other active breeding sites in northern Ontario at that time may have included Rupert Bay in southern James Bay, more than 500 km north, where breeding occured in 1912, the 1940s (200 nests) and 1995 (42 active nests in 1995; Tymstra 1997), and Lake Abitibi, 260 km northeast, where undetermined numbers bred since at least 1982 (Chuck McCrudden, personal communication). Thus, sightings in the Sudbury Region within 35–40 km of the city during the late 1970s to mid-1980s, which were exclusively in the spring, could have been of birds from Georgian Bay that had wandered inland or "overshot" their migratory destination.

Alternatively, they could have been migratory birds en route to James Bay or Lake Abitibi. The lack of resident birds suggests their stays were short and that they went (returned) elsewhere to breed.

Cormorants were first "resident" in the Sudbury Region at Kelley Lake in 1987–1989, when 1–2 birds remained each summer. Summer numbers increased annually after 1990 until breeding occurred in 1996 (C. Blomme, unpublished data). The increasing number of non-breeders at Kelley Lake, April–October, 1990–1996, may have resulted from wandering imma-

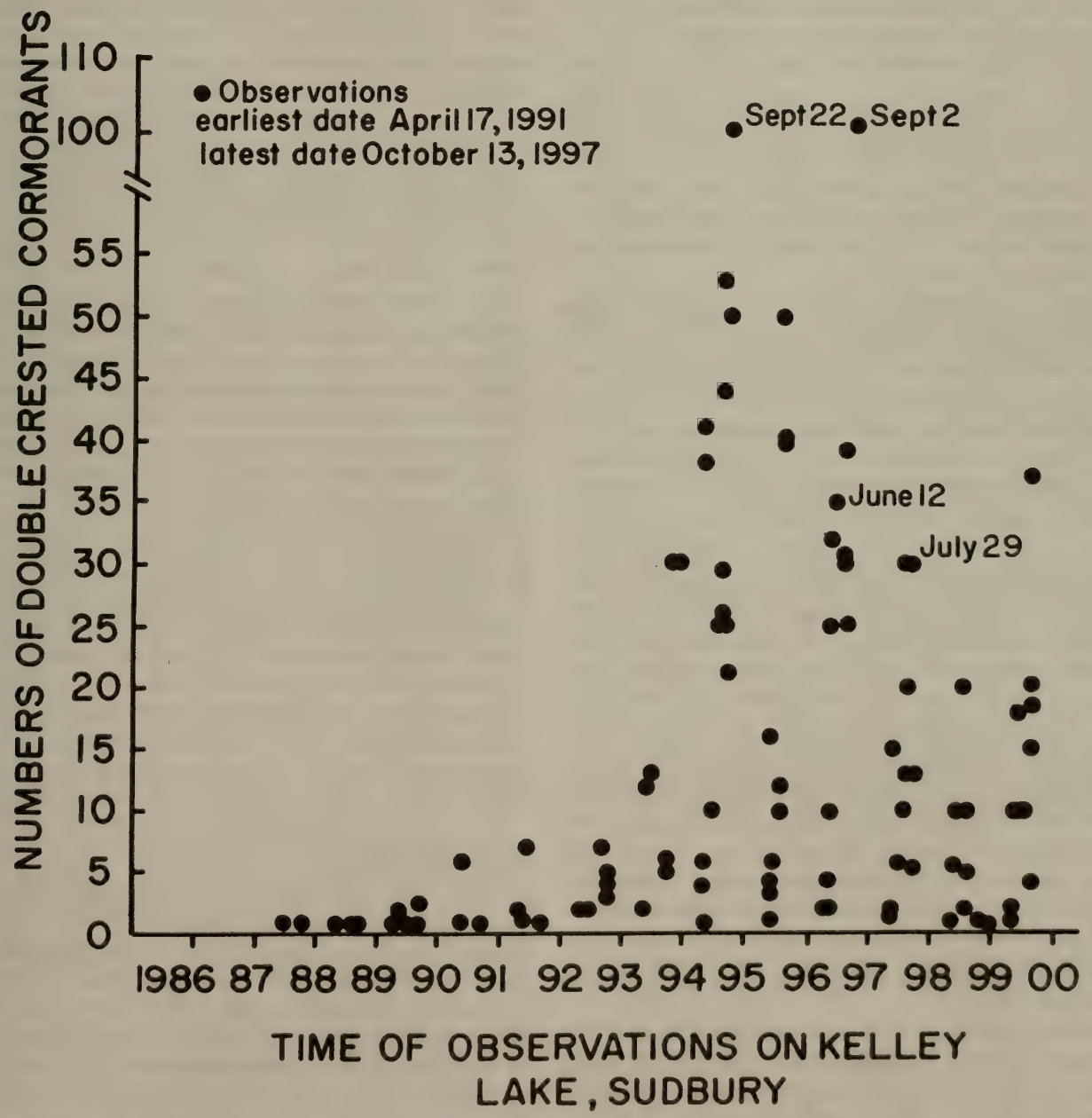

FIGURE 2. Plot of numbers of Double-crested Cormorants seen on a given date between 1986 and 1999 at Kelley Lake, Sudbury, Ontario. Maxima of over 100 birds were seen on 22 September 1994 and 2 September 1996 and represent migrants as well as resident birds. 12 June 1996 and 29 July 1997 show nest confirmation dates.

ture birds, adults which failed as breeders elsewhere or that, for some reason, did not breed at another colony site, or additional birds overshooting their Lake Huron destinations. It is unlikely they were actively breeding birds from other colonies as they would not have taken up residence away from their nesting colony. Kelley Lake thus became a population centre for non-breeding birds. During this time, colonies in northern Georgian Bay continued to grow, from 840 nests in 1990 to 3000 nests in 1997 (DVW, unpublished data), so there would have been ample immature birds and inexperienced adult birds looking for nest sites. Cormorants are often "resident" at a site several years before they eventually breed there (Hatch and Weseloh 1999).

In the late 1980s and early 1990s, new colonies continued to appear in northern Ontario. They were discovered at: Ella Islet, Lake Superior, near Wawa, 340 km NW of Sudbury, with two nests in 1989 (Blokpoel and Tessier 1993) and 138 nests in 1999 (DVW, unpublished data), and Lake Nipissing, 70 km east of Sudbury, in 1993 (and possibly earlier); numbers there grew from 638 to 1600 nests from 1995 to 1999 (26%/yr; Richard Rowe, personal communication). Immature and inexperienced adults taking up residence at Kelley Lake might have come from these colonies.

In the early 1990s the number of sightings in the Sudbury Region increased (Table 2). These birds were probably dispersing locally from Kelley Lake to other lakes to feed, as those lakes were within the usual daily foraging range for cormorants, up to 30 km (Custer and Bunck 1992). In 1993, cormorants first started being observed on lakes in the outlying Sudbury region, primarily in August and September (data set A). Birds at lakes close to Georgian Bay (i.e., lake numbers 31 and 34) probably came from the Bay, as the flight distances would be < 5 km. Alternatively, they could have been migrants from farther north, including Kelley Lake and Wanapitei Lake. Birds observed at lakes farther from Georgian Bay (i.e., lake numbers 2, 4, 28, 58 and 84) were more likely to be from Wanapitei or Kelley Lakes. Alternatively, they could have been autumn migrants from breeding sites farther north, but given the orientation of the rivers to the north, they would have been autumn migrant stragglers or other wandering birds. It is unlikely these birds came from Georgian Bay, as cormorants are not known to make northward post-fledging dispersal as do some herons (Dolbeer 1991).

Birds reported in this study (especially prior to summer residency being established at Kelley Lake) were not observed to fly inland but rather "appeared" or were found at inland sites. In almost all cases, these inland sites were far enough removed from the "large lakes" that the cormorants' appearance at them was probably not the result of foraging flights from a breeding colony. Thus there are at least two kinds of inland occurrences of cormorants. The first involves stragglers that either strayed off a migratory route or were not attached to a colony and were wandering. If, in any given area, the number of these individuals gradually increases, new colonies may form. This appears to fit most of the birds seen in early years of this study and may be how the colonies at Kelley and Wanapitei Lakes were formed.

The second type of inland occurrence is that of birds dispersing inland on a daily basis from a breeding colony or some other roosting situation. This probably accounts for many of the sightings in the immediate Sudbury area once cormorants had established summer residency at Kelley Lake; i.e., birds left Kelley Lake each morning to feed in the surrounding area, and returned to Kelley to roost. This is also a type of behaviour that has been reported at several Great Lakes coastal cities/towns where cormorants have been observed flying inland along river courses; e.g., in Ontario at Kingston (DVW, personal observation), Parry Sound (R. Black, Ontario Ministry of Natural Resources), Blind River (S. Elliott, Ontario Ministry of Natural Resources) and in New York near Watertown (I. Mazzocchi, New York State Department of Environmental Conservation). These flights may or may not lead to formation of new colonies depending upon the status of the birds involved. Birds with a firm position at a breeding colony (i.e., a mate, nest and eggs or young), would have a strong motivation to return to their home colony. Non-breeding birds or perhaps newly established birds at the periphery of the colony could be attracted to new inland sites by the prospect of reduced intra-specific competition.

What impact do cormorants have on inland wildlife? Long-term monitoring of presence and breeding on inland waters is needed in the Sudbury region. Inland waters in other portions of the Great Lakes watershed should be searched. Research into the impacts on other birds and on fish in the Sudbury region could have implications throughout the Great Lakes watershed. Radio-tracking could be used to determine the origin of the birds using small inland lakes.

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Seasonal Distribution of Waterbirds in Relation to Spawning Pacific Herring, *Clupea pallasi,* in the Strait of Georgia, British Columbia

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About 3500–3700 waterbirds were present in 23 bays and beaches along 150 km of shoreline on the east coast of Vancouver Island, British Columbia prior to the arrival of Pacific Herring (*Clupea pallasi*). Waterbird abundance in the region increased to > 32 500 individuals when herring spawned in March with the greatest proportional increase occurring at the spawn site. Another 140 000 waterbirds were present outside the study site in deep water a few km offshore. Waterbird density in the entire study area increased from a low of about 66 birds/km^2 prior to the arrival of herring to a peak density of about 616 birds/km^2 when the herring spawned on the beaches.

Key Words: Loons, grebes, seabirds, sea ducks, gulls, Pacific Herring, *Clupea pallasi*, Strait of Georgia, British Columbia.

From February to April, large flocks of birds are attracted to schools of Pacific Herring (*Clupea pallasi* Valenciennes 1847) that spawn in shallow waters along the Pacific coast of Canada (Munro and Clemens 1937; Haegele and Schweigert 1989; Haegle 1993; Vermeer et al. 1997). One of the largest spawning sites in western Canada is on the western shore of the Strait of Georgia in southern British Columbia. Herring enter the Strait of Georgia in early winter to deposit eggs in late February and early March (Hay et al. 1989). The eggs hatch about 14 days after they are deposited and the larvae form into schools that depart for deep water in April (Haegele and Schweigert 1989). At least 21 waterbird species eat Pacific Herring or their eggs in British Columbia including Western Grebe (*Aechmophorus occidentalis*), Brandt's Cormorant (*Phalacrocorax pencillatus*) and Pelagic Cormorant (*Phalacrocorax pelagicus*), Brant (*Branta bernicla*), Black Scoter (*Melanitta nigra*), Surf Scoter (*Melanitta perspicillata*), White-winged Scoter (*Melannita fusca*), Harlequin Duck (*Histrionicus histrionicus*), Long-tailed Duck (*Clangula hyemalis*), Greater Scaup (*Aythya marila*), Common Goldeneye (*Bucephala clangula*), Barrow's Goldeneye (*Bucephala islandica*), Bufflehead (*Bucephala albeola*), Common Merganser (*Mergus merganser*), Red-breasted Merganser (*Mergus serrator*), Surfbird (*Aphriza virgata*), Black Turnstone (*Arenaria melanocephala*), Glaucous-winged Gull (*Larus glaucescens*), Mew Gull (*Larus brachyrhynchos*), California Gull (*Larus californicus*), and Marbled Murrelet (*Brachyramphus marmoratus*) [Grosz and Yocom 1972; Haegele 1993; Vermeer et al. 1997; RWB, personal observation].

Large numbers of waterbirds attracted to beaches with spawning Pacific Herring in British Columbia (Vermeer 1981; Haegele 1993; Vermeer et al. 1997) are potentially at risk to a single oil spill and to commercial exploitation of herring. The numbers of waterbirds attracted to spawning sites originate from a wide but undocumented area. It is also unknown how different species utilize the spawn. Here, we describe the magnitude of regional shifts in abundance of waterbirds at one spawn site in relation to the arrival of adult Pacific Herring, the presence of herring eggs and the emergence of larval herring.

Methods and Study Site

The Strait of Georgia is a 200 km long body of water separating Vancouver Island from the mainland of British Columbia (Vermeer and Butler 1989). The east coast of Vancouver Island includes many small bays with rocky, gravel or sand substrates frequented by sea ducks, loons, grebes, shorebirds, and seabirds in fall, winter and spring. Each spring, Pacific Herring spawn in Lambert Channel and neighboring bays in the Strait of Georgia (Figure 1). We counted waterbirds in 23 bays and beaches between Nanaimo and Campbell River including Lambert Channel, once a week for 10 weeks between 19 February and 23 April 1998 (Figure 1). The sites were Nanaimo estuary, Departure Bay, Piper's Lagoon, Oar Road, Snaw-na-as dock, Nanoose Bay, Rathrevor Beach, Parkville Beach, Qualicum Beach, Qualicum Bay, Deep Bay, Fanny Bay, Buckley Bay, Fillongley Park, Hornby Ferry Terminal, 1565, Union Bay, Royston Beach, Comox Harbour, Comox Ferry Terminal, Oyster River, Willow Point, and Campbell River. All surveys were made from land through 8 power binoc-

FIGURE 1. Surveyed area on Vancouver Island showing the location of 23 beaches included in this survey and the major Pacific Herring spawning site in Lambert Channel in 1998.

ulars and a 15–45× or 20–60× telescope. All birds seen on or flying over the water within approximately 1 km of shore were tallied to species on most days and grouped by genus or family when identification to species was difficult as a result of poor visibility on windy days.

Herring were visible by the presence of ripples on the water surface when schools moved close to shore, and spawning was evident when the water turned a milky color from the release of sperm. Herring eggs require about 14 days to hatch (Haegele and Schweigert 1989). We divided our waterbird censuses into five time periods to coincide with stages of the herring spawning season as follows: (1) the *pre-spawn* stage was defined as the period before herring schools were first seen in the study area (< 26 February), (2) the *adult fish* stage was estimated from when herring were first observed until the day before spawning began (27 February to 12 March), (3) the *spawning* stage occurred from when sperm was first noted until 14 days later when the first eggs were estimated to have hatched (13 to 27 March), (4) the *early larval* stage was estimated to begin two weeks after the start of the spawning period and ran for a further two weeks (*i.e.*, >27 March–9 April), and (5) the *late larval stage* ran from 10–23 April. We estimated the surveyed area of each of the 23 sites (Figure 1) by the proportional area of water within 1 km radius of the survey point.

Results

A total of 93 703 birds representing 28 species or families of birds were counted over all surveys (Table 1). The four most abundant taxa were scoters (36.3%), gulls (18.2%), Brant (12.4%) and scaup (11.7%). The number of waterbirds present in the study area during the herring spawn seasons exceeded the late winter pre-spawn counts for at least 49 days. During the pre-spawn stage, we estimated between 3507 and 3718 waterbirds, of which over half were scoters (55.5%), frequented the bays and beaches in the study area (Table 2). Nearly 21 000 birds were present during the adult fish stage and over 32 500 birds were present at the end of the spawning period (Table 2). The number of waterbirds declined to between 6 991 and 13 325 individuals during the herring larval stages (Table 2).

The influx in waterbirds was noticeable throughout the study area but the greatest proportional increase occurred at the major spawn site in Lambert Channel. This channel held only about 200 birds prior to the arrival of herring but abundance grew to

TABLE 1. Total number of waterbirds counted during 10 surveys of the east coast of Vancouver Island between Nanaimo and Campbell River, British Columbia, 19 February to 23 April 1998.

Species	Scientific Name	Number	%
Common Loon	*Gavia immer*	894	1.0
Pacific Loon	*Gavia pacifica*	1776	1.9
Western Grebe	*Aechmophorus occidentalis*	765	0.8
Red-necked Grebe	*Podiceps grisgena*	1024	1.0
Horned Grebe	*Podiceps auritus*	803	0.9
Double-crested Cormorant	*Phalacrocorax auritus*	219	0.2
Pelagic Cormorant	*Phalacrocorax pelagicus*	187	0.2
Trumpeter Swan	*Cygnus buccinator*	8	<0.1
Brant	*Branta bernicla*	11648	12.4
Canada Goose	*Branta canadensis*	41	<0.1
Mallard	*Anas platyrhynchos*	731	0.8
American Wigeon	*Anas americana*	3728	4.0
Northern Pintail	*Anas acuta*	340	0.4
Dabbling Duck spp.[a]	*Anas* spp.	4081	4.4
Greater Scaup	*Aythya marila*	1701	1.8
Lesser Scaup	*Aythya affinis*	31	<0.1
Scaup spp.[b]	*Aythya* spp.	9269	9.9
White-winged Scoter	*Melanitta fusca*	3400	3.6
Black Scoter	*Melanitta nigra*	2187	2.3
Surf Scoter	*Melanitta perpicillata*	11146	11.9
Scoter spp.[c]	*Melanita* spp.	17322	18.5
Harlequin Duck	*Histrionicus histrionicus*	613	0.7
Long-tailed Duck	*Clangula hyemalis*	687	0.7
Barrows Goldeneye	*Bucephala islandica*	50	<0.1
Common Goldeneye	*Bucephala clangula*	801	0.9
Bufflehead	*Bucephala albeola*	2032	2.2
Common Merganser	*Mergus merganser*	42	<0.1
Red-breasted Merganser	*Mergus serrator*	901	1.0
Gull spp.[d]	*Larus* spp.	17021	18.2
Pigeon Guillemot	*Cepphus columba*	32	<0.1
Marbled Murrelet	*Brachyramphus marmoratus*	223	0.2
Total		93 703	

[a]*Anas platyrhynchos* and *A. americana*. [b]most likely *Aythya marila*. [c]*Melanitta nigra, M. perspicllata*, and *M. fusca*. [d]*Larus glaucescens, L. californicus, L. brachyrhynchos*.

over 12 600 birds by the end of the spawn stage (Table 2). Many more birds were present than our surveys indicated. One estimate of the offshore flocks made from a boat in late March reported about 140 000 waterbirds (I. Goudie, CWS, Delta, personal communication). The seasonal significance of herring spawn to the presence of waterbirds on the east coast of Vancouver Island is illustrated well by the censuses in Lambert Channel. The density of birds was about 80 times greater when herring were present than prior to their arrival (Table 3). Soon after the herring spawned, the number of waterbirds plummeted in Lambert Channel but they were still more abundant than during the pre-spawn period.

The predominant waterbirds prior to the arrival of herring in Lambert Channel were scoters (82.8%) and the Harlequin Duck (14.5%). Gulls (76.7%) followed by scoters (16.3%) were the most numerous birds during the adult fish stage (Table 3). We did not count the gulls in the pre-spawn stage although we noted small numbers. Scoters (43.5%), gulls (20.6%) and Long-tailed Duck, cormorants and scaup (7.9–9.7%) predominated during the spawn stage. The herring early larval stage was predominated by a large influx of migrating Brant (50.6%), gulls (26.3%), and Bufflehead (12.0%). Scoters (42.6%), Brant (29.9%) and Pacific Loons (19.6%) were the predominant avifauna during the late larval stage.

The occurrence of many species of waterbirds in Lambert Channel coincided with the herring reproductive stage that matched their particular food preference. The Common Loon was significantly ($P < 0.001$) more numerous when adult Herring were present. Cormorants, scaup, scoters, Common Goldeneye, Long-tailed Duck, and gulls were significantly ($P < 0.001$) more numerous in late March when Herring were spawning (Table 3). The number of grebes present during the spawn and early larval stages was not significantly different ($P > 0.05$) but they were significantly ($P < 0.01$) more numerous during the early larval stage than the late larval stage.

TABLE 2. Total number and density (birds/km^2) of waterbirds counted at 20 sites on the east coast of Vancouver Island and three sites in Lambert Channel, 19 February–23 April 1998.

Spawning stage[a]	Date	Number (density) of birds Vancouver Island sites	Number (density) of birds at Lambert Channel	Number (density) at all sites
Pre-spawn	19 February	3 492 (68.1)	226 (144.0)	3 718 (70.4)
	24 February	3 313 (64.6)	194 (123.6)	3 507 (66.4)
Adult fish	05–06 March	9 295 (181.2)	4 218 (2686.6)	13 513 (255.9)
	11–12 March	4 953 (96.6)	16 012 (10198.7)	20 965 (397.1)
Spawn	18–19 March	15 531 (302.7)	10 487 (6679.6)	26 018 (492.8)
	25–26 March	19 860 (387.1)	12 661 (8064.3)	32 521 (615.9)
Early larval	01–02 April	10 150 (197.9)	1 256 (800.0)	11 406 (216.0)
	08–09 April	6 253 (121.9)	738 (471.3)	6 991 (132.4)
Late larval	16–17 April	8 684 (169.3)	953 (607.0)	9 537 (180.6)
	23 April	12 172 (237.3)	1153 (734.4)	13 325 (252.4)
Total		93 703 (1826.6)	47 899 (30509.6)	141 601 (2681.9)

[a]*pre-spawn* stage < 26 February; *adult fish* stage 27 February to 12 March; *spawning* stage 13 to 27 March; *early larval* stage 27 March–9 April; and *late larval* stage 10–23 April

The number of Brant was significantly smaller during the spawning stage than either the early or late larval stages.

Discussion

The arrival of herring along the coast of British Columbia in late winter and spring creates a seasonal bonanza of food for thousands of waterbirds (Munro and Clemens 1937; Haegele and Schweigert 1989; Haegele 1993; Vermeer et al. 1997). The high density of birds reported indicated that many species moved to herring spawn sites but the distances they traveled was unknown. Our data showed that the seasonal increase in abundance was many times greater than the pre-spawn estimates in the study area indicating that many waterbirds might have traveled more than 80 km to eat herring in Lambert Channel. It is unlikely that the large flocks counted in Lambert Channel were the cumulative total from bays we did not survey between Nanaimo and Campbell River because we recorded increased numbers of waterbirds in all bays, including Lambert Channel. The number of waterbirds present in the study area was greater when herring spawned than during the pre-spawn period and many more settled offshore. The combined single offshore estimate of 140 000 waterbirds a few kilometers outside our study area and our peak shoreline estimate of 32 521 waterbirds in the study area in late March (Table 2) suggest that about 170 000 waterbirds might have been present during the Herring spawn event in 1998. Compared with the 3507 waterbirds present

TABLE 3. Number of waterbirds in Lambert Channel prior to the arrival of Pacific Herring, and during the adult fish, egg, and early and late larval Pacific Herring stages. nd = no data. Different superscripts indicate significant differences between stages ($P < 0.05$).

Species	Pre-spawn	Adult fish	Spawn	Early larval	Late larval
Common Loon	0	168^A	24^B	6^C	22
Pacific Loon	1	0	12	0	406
Red-necked Grebe	0	0	5^A	6^A	0
Horned Grebe	2	0	17^A	23^A	8^B
Cormorant spp.	3	150^A	2 000^B	4^C	8
Brant	0	146^A	446^B	974^C	618^D
Scaup spp.	0	915^A	1 835^B	8^C	0
Scoter spp.	188	3 268^A	10 059^B	33^C	881
Harlequin Duck	33	7	0	0	0
Long-tailed Duck	0	0	2234^A	7^B	0
Common Goldeneye	0	0	968^A	41^B	0
Bufflehead	0	0	661^A	230^B	13^C
Red-breasted Merganser	0	0	97	85	72
Gulls	nd	15 350^A	4775^B	506^C	39^D
Total (all birds)	227	19 997	23 133	1 923	2 067

prior to the spawn, this indicates a 48-fold increase in waterbirds on the east coast of Vancouver Island.

Our observations generally supported our hypothesis that the timing of arrival of waterbirds coincided with the presence of their diet preferences. Loons were most numerous when adult fish were schooling offshore in deepwater, gulls, grebes and cormorants pursued adult fish when they entered the shallows to spawn and diving ducks gorged on herring eggs. Vermeer et al. (1997) and Reed et al. (1998) suggested that Brant intentionally ingest herring eggs clinging to Eelgrass (*Zostera marina*) and Haegele (1993) reported Brant eating herring eggs from the beaches in Lambert Channel, which we also observed in our study. Brant occur on beaches with herring spawn in significantly larger flocks than in areas without spawn (Vermeer et al. 1997). However, the number of Brant was significantly smaller during the spawning stage when eggs were most numerous on eelgrass than either the early or late larval stages.

Waterbirds are reported to consume a very small proportion of the total egg mass laid by herring (Haegele and Schweigert 1989; Haegele 1993) but the importance of herring as a source of food energy for waterbirds has not been quantified. Our study was not designed to examine this relationship specifically. Loons, grebes, and waterfowl that have been reported to occur at herring spawn events, migrate from the Strait of Georgia during or soon after herring depart for deep water in late March and early April (Campbell et al. 1990). Herring, eggs, and larvae could possibly provide for a rapid gain in lipids that waterbirds might use to power migratory flights to other herring spawning beaches or to the breeding grounds. The migrations of several shorebirds coincide with a seasonal abundance of herring eggs and invertebrate prey (Gratto et al. 1984; Hicklin 1987; Norton et al. 1990; Clark et al. 1993). If our hypothesis is correct, then the fitness of many waterbirds along the east coast of Vancouver Island and perhaps other regions of the Strait of Georgia and Puget Sound may be closely linked to the quantity and duration eggs and Herring are available to them on beaches in spring.

Acknowledgments

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North Atlantic Sperm Whale, *Physeter macrocephalus*, Strandings on the Coastlines of the British Isles and Eastern Canada

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Goold, John C., Hal Whitehead, and Robert J. Reid. 2002. North Atlantic Sperm Whale, *Physeter macrocephalus*, strandings on the coastlines of the British Isles and Eastern Canada. Canadian Field-Naturalist 116(3): 371–388.

Sperm Whale stranding records for the British Isles and Eastern Canada were analysed to investigate short and long term stranding trends on either side of the North Atlantic Ocean. Annual stranding events across a ten year period from 1988 to 1997 showed no significant trend with time in either the British Isles or eastern Canada, although stranding events were nearly three times as numerous on the Scottish coast during this period than in any other region. Strandings during this period occurred throughout the year in Scotland, Ireland and eastern Canada, but peaked in the autumn and winter periods. Strandings on the English coast were the least numerous and occurred only in the autumn and winter. Decadal analysis of stranding events for the 20th Century as a whole showed significant exponential increases in Sperm Whale strandings in all regions of the British Isles (except England due to small sample size). Decadal stranding events were fitted to an exponential model which revealed a rate of increase of 14%/yr for the British Isles as a whole, beginning at about 1970. The stranding rate on the Scottish coast, 18%/yr, was twice that for Ireland, 9%/yr, with most of the strandings increase occurring in the offshore Scottish Islands. The time series data for eastern Canada was of insufficient extent to conduct a rigorous decadal analysis. Almost all stranded Sperm Whales on the British and East Canadian coasts have been males. Sperm Whale strandings have been most dense, and have increased fastest, in the offshore Scottish islands of Hebrides, Orkney and Shetland. The data support no firm conclusions but valid hypotheses include increased reporting and anthropogenic effects, which may be acting synergistically. The increase in the British data is too dramatic to have been caused solely by a simple increase in Sperm Whale population size.

Key Words: Sperm Whale, *Physeter macrocephalus,* stranding, Canada, British Isles, noise, pollution, seismic, Atlantic.

A number of widely publicised Sperm Whale (*Physeter macrocephalus* Linnaeus 1758) strandings along the coastline of the British Isles (see Geographic Terminology below) in recent years has raised the profile of these events and given rise to much speculative comment. There is a general perception that strandings of Sperm Whales are increasing although the evidence is seldom critically examined. Previous works indicate an increase in the number of reported strandings on the British coastline (Berrow et al. 1993; Evans 1997), although the causes of such a trend remains elusive. If Sperm Whale strandings are on the increase, then why? Possible causes include: increased reporting of a steady stranding rate; increased density of Sperm Whales in the area of the British Isles; and increased mortality of Sperm Whales per capita of population. Such possible causes are not mutually exclusive, and could be operating synergistically if, for example, changes in migration patterns have increased the exposure of animals to anthropogenic threats.

In this paper we examine geographic and temporal patterns of Sperm Whale strandings in both British and eastern Canadian waters in order to quantify stranding trends. Different causes of an increase would imply different geographic and temporal patterns of strandings, and therefore we are able to make some progress in narrowing down potential causes. For instance, as all Sperm Whales in the North Atlantic are thought to belong to the same population (Donovan 1991), a general increase in population should be reflected on both sides of the Atlantic and be consistent with models of Sperm Whale population dynamics. Our analysis initially considers the most recent strandings on the British and East Canadian coastlines. We then relate these recent strandings to historical records as documented in the literature, and consider potential factors relevant to stranding trends. Further, given the disparate archiving of data that currently exists, which is often difficult to access, we present the raw strandings data in appendices as a single, easily referenced repository of knowledge for future generations.

Geographic Terminology

British Isles: The land masses comprising England, Scotland, Wales, Northern Ireland and the Republic of Ireland.

Atlantic Frontier: That part of the Atlantic Ocean north and west of the British Iles.

Eastern Canada: The provinces of Newfoundland & Labrador, Nova Scotia, New Brunswick, Prince Edward Island, and Quebec.

Methods

Regional Collection of Stranding Data

Since 1913 a strandings reporting scheme has been operated by the British Natural History Museum in London. Strandings of all species have been recorded since that time, although reporting has been opportunistic. In recent years, responsibility for the collection of cetacean stranding data in the British Isles has been more formalised under the auspices of four regional bodies. In England, the London Natural History Museum continues to archive cetacean stranding records and, through an affiliation with the Institute of Zoology, has the remit of post-mortem examination of stranded carcasses. In the principality of Wales, a designated strandings co-ordinator affiliates with veterinary pathologists to obtain comparable information; with strandings and post-mortem data from the principality ultimately archived along with the English records at the Natural History Museum (NHM). In Scotland, these tasks are undertaken by the SAC Veterinary Science Division, from where one of the authors (Reid) conducts post mortem examination of stranded cetaceans. The England and Wales stranding scheme was put on a statutory footing in 1990 with funding from the Department of the Environment (now DETR). The Scottish scheme attained similar status in 1992. Cetacean strandings data in Ireland are compiled by the Irish Whale & Dolphin Group (IWDG), with post mortem examination of beached carcasses carried out by the University College, Cork.

Cetacean stranding data in Eastern Canada are collected by volunteer stranding groups in each of the five provinces bordering the Atlantic (Newfoundland and Labrador, Nova Scotia, New Brunswick, Prince Edward Island and Quebec). These are usually linked to provincial museums, local universities and/or the federal Department of Fisheries and Oceans. In the special case of Sable Island, Nova Scotia, which has one of the highest rates of cetacean strandings in the world (Lucas and Hooker 2000), a resident naturalist (Z. Lucas) keeps records of all events. Very low human population densities probably mean that there is substantial undereporting of strandings in the northern part of the Sperm Whales' range off eastern Canada, especially Labrador.

Analysis of Strandings Data

Recent Data

Recent data for Britain and eastern Canada (1988 to 1997 inclusive) have been collated in this exercise and treated by region as numerical records showing numbers of animals stranded per year and number of stranding events per year (i.e., two or more whales stranding together are considered as one event). These events are plotted on charts to give an indication of their geographic distribution around the respective coastlines. Correlation analysis of stranding events vs. year is applied to determine whether temporal trends (i.e., increase or decrease with time) exist within the initial ten year period under investigation for any given region. The raw data are further tabulated to show seasonality of strandings with number of stranded animals and the associated events grouped into quarterly periods.

Historical Data

Historical strandings data, from the official publications of NHM archive data and IWDG data, are then considered and used to set the more recent data within an extended temporal context. British stranding records are available from 1913 in the case of England, Wales and Scotland (Harmer 1927; Fraser 1934, 1946, 1953, 1974; Sheldrick 1989; Sheldrick et al. 1994), and 1901 in the case of Ireland (Berrow and Rogan, 1997). There are no extensive historical records from eastern Canada, although records are available for Sable Island, Nova Scotia, from 1970 onwards (Lucas and Hooker 2000; Lucas, personal communication). However, records prior to 1987 were collected inconsistently and hence a decadal analysis is not attempted here, even for Sable Island.

For historical comparison, the strandings data, (i.e., numbers of animals and events) are summed within ten year periods working retrospectively from the date of the most recent available data; this defines the most recent decade as the period 1988-1997 inclusive. The data are tabulated in this decadal format and regional trends plotted. Statistical modelling of the trends is performed using non-linear regression, and is only performed on the events data, as this analysis is not valid for numbers of animals *per se* due to non independence. Only decadal periods for which observations are complete are analysed (i.e., the 1908–1917 decade for Scotland and England is excluded – for consistency this decade is also excluded for Ireland).

Finally, the decadal stranding data for the remote Scottish Islands are separated from that of mainland Britain to yield insight into whether remote locations and the associated human communications may have led to a differential rate of reporting over historic time, and/or whether anthropogenic factors might differentially affect the outer islands.

Statistical modelling

Rates of increase in stranding events were calculated by fitting (using least-squares) the following exponential model to the number of stranding events, n^i, in each year, i (using non-linear regression in SYSTAT):

$$n_i = k(1 + b^{(i-c)}) + \text{error} \quad \text{(equation 1)}$$

This models an exponential increase from a basal rate of stranding events per year k, taking off at approximately year c, and then increasing at a rate b per year.

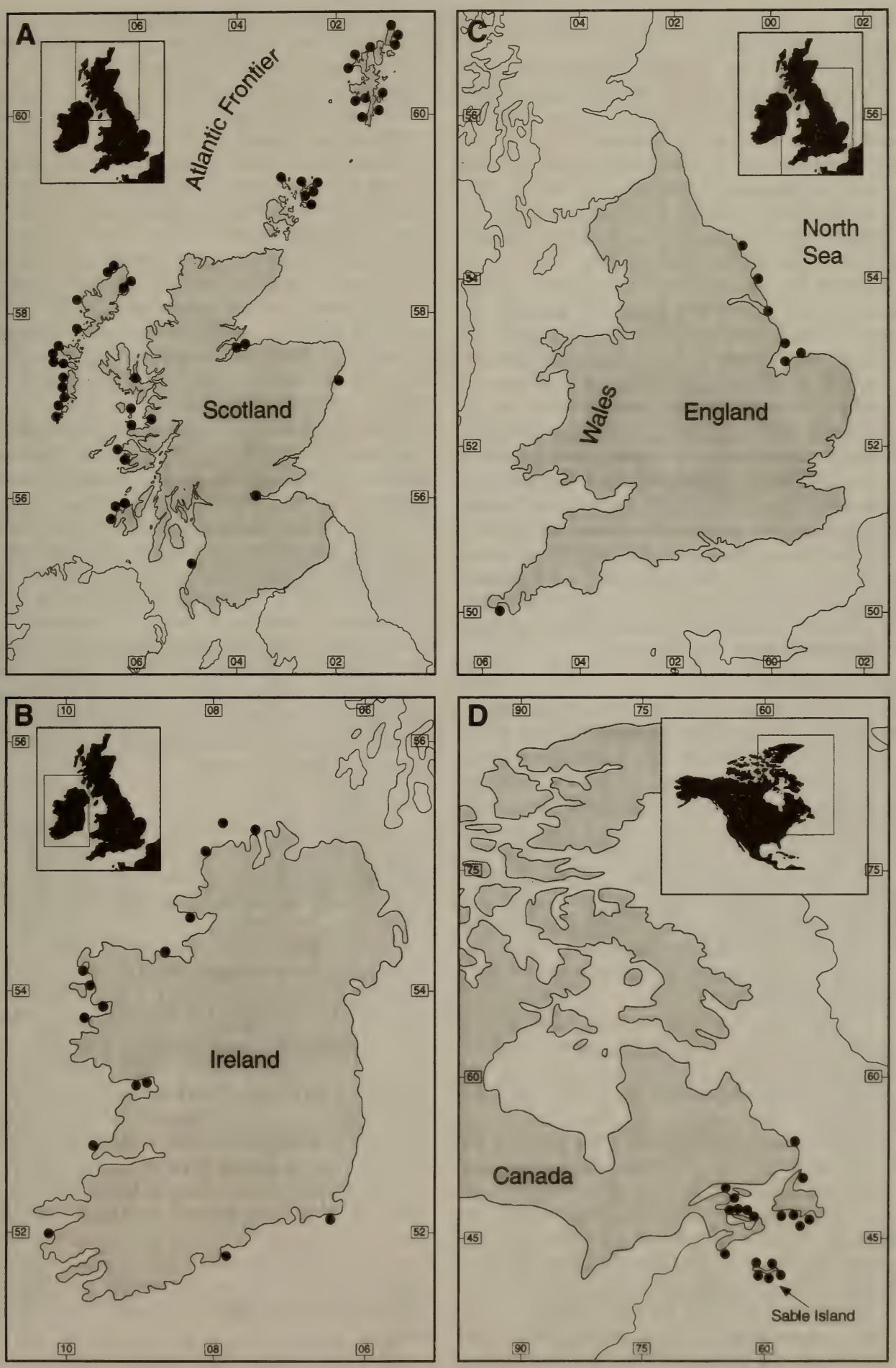


FIGURE 1. Distribution of Sperm Whale stranding events around the British and Eastern Canadian coastlines, 1988–1997 inclusive. Scotland (A); England & Wales (B); Ireland (C); and Eastern Canada (D).

Results

Geographic Distribution

Figure 1 shows the geographic distribution of the most recent decade (1988 to 1997) of Sperm Whale strandings, around the British and eastern Canadian coastlines. In the case of Scotland [Figure 1A], where strandings are most numerous, there is a clear tendency for strandings to occur on the western margins of the Scottish mainland as well as the Outer Hebrides, Orkney Islands and Shetland Islands. There are some clear instances, from Appendix A and Figure 1A, of east coast strandings (e.g., six whales at Cruden Bay, Grampian) but generally the pattern is one that reflects the Atlantic margin. On the Irish Coast [Figure 1B] strandings are again predominantly along the western margin, bordering the Atlantic Ocean. Strandings on the coastlines of England and Wales [Figure 1C] are less numerous and mainly occur along the eastern margin (North Sea coast), there have be\en no Sperm Whale strandings on the coast of Wales. Strandings on the east Canadian coast are concentrated around the areas of Newfoundland, Nova Scotia and Sable Island. However, it is acknowledged that the low human population densities in the northern part of the continent probably results in substantial under reporting in northern regions of Canada.

Data Observations

Table 1 summarises annual numbers of animals stranded and the associated number of events during the period 1988 to 1997 for each of the four regions. Figure 2 illustrates these data and several important features can be seen. There have clearly been many more strandings on the Scottish coast than on either the Irish or eastern Canadian coasts, evident by virtue of the fact that all the plots in Figure 2 are on the same vertical scale. There are no visually convincing trends, or statistically significant correlations, between year and stranding rate ($P > 0.2$ for each area separately, and for the British Isles as a whole), in the 1988 to 1997 data — i.e., there is neither a clear increase or decrease in strandings with time during this period for any of the regions. Although there are two notable examples of mass stranding in the Scottish data, the trend is generally one of single whale strandings. The English data show single whale strandings in all but one case and the Irish data show only single whale strandings. Multiple strandings are, by contrast, relatively common in eastern Canada (one third of all events). The differences in the proportion of multiple strandings between the three regions (excluding England because of low sample size) are significant (contingency-table test, $G = 10.76$, 2 d.f., $P < 0.01$).

Table 2 summarises the seasonality of strandings during the ten year period 1988 to 1997, and the data are illustrated graphically in Figure 3. The Scottish and eastern Canadian data show peak numbers of animals stranding in the autumn and winter, although the trend is less clearly pronounced in the number of events. The Irish data are similar but lack the peak during the October-December quarter. The English data are less numerous but similarly only show events in the Autumn and Winter.

Table 3 summarises all documented stranding data for the twentieth century to 1997 as consecutive ten year totals for Scotland, Ireland, England and Nova Scotia (Sable Island). Sable Island is the only Canadian region for which moderately extended records exist, however even for this region data prior to 1987 were collected inconsistently, hence it is not included in further analyses. The data for Scotland, Ireland and England are graphically presented in Figure 4, which shows increases in reported stranding events with time in all regions. The picture is quite striking in the cases of Scotland and Ireland, showing essentially exponential increases in both numbers of whales stranding and the number of stranding events towards the end of the twentieth century.

Table 4 summarises the re-worked data as England + Mainland Scotland vs. the more remote Scottish Islands of the Hebrides, Orkney and Shetland. Figure 5 graphically presents the respective trends. Stranding events (and numbers of animals involved) once again show an upward trend for both mainland Britain and the offshore Scottish islands. The Scottish islands account for a greater proportion of stranding events during the most recent decade than during earlier decades, and hence show the greater rate of increase.

Numerical Analysis

Non-linear regression analysis, using the model of equation (1), yields rates of increase of Sperm Whale stranding events for the whole of the British Isles of approximately 14% per year, beginning at around 1970, which is significantly different from zero (Table 5). There are also substantial, and significant, increasing trends when Scotland, Ireland and England are treated separately. The Scottish rate of increase, 18%/yr, is twice that for Ireland, 9%/yr, and the difference between the two is significant (t-test approximation $P<0.05$). There are substantially fewer data for England, so estimates are less precise and a significance level cannot be ascribed. There is, however, a significant difference between the stranding rates for Mainland Scotland + England vs. the Scottish Islands. The rates of increase stand at 11% /yr from about 1960 for the mainland, and 19%/yr from about 1973 for the Scottish islands. These model results are presented graphically in Figure 6. Stranding events across the British Isles more than doubled during the last two decades of the twentieth century.

Discussion

There is a general pattern around the British Isles

TABLE 1. Strandings of Sperm Whales from 1988–1997 inclusive.

	Scotland		England & Wales		Ireland		Eastern Canada	
Year	Whales	Events	Whales	Events	Whales	Events	Whales	Events
1988	7	7	0	0	4	4	1	1
1989	6	6	0	0	0	0	7	2
1990	4	4	1	1	4	4	6	2
1991	0	0	1	1	0	0	6	3
1992	5	4	0	0	0	0	6	4
1993	3	3	2	2	1	1	0	0
1994	18	8	1	1	1	1	2	2
1995	4	4	0	0	1	1	1	1
1996	9	4	0	0	1	1	4	4
1997	5	5	3	2	3	3	4	2
TOTAL	61	45	8	7	15	15	37	21

of Sperm Whale strandings on the western margins bordering the Atlantic Ocean. This might be expected for a species that is adapted to a deep water habitat, and which may prefer the submarine slope waters at the edge of the European continental shelf. Data for the most recent ten year period show that there is no statistically significant trend in the number of Sperm Whale stranding events on either the British or eastern Canadian coastlines. This observation contrasts strongly with multi-decadal examination of strandings, which reveals a substantial increase in the latter half of the twentieth century across the British Isles as a whole, with Scotland exhibiting the greatest rate of increase. The question

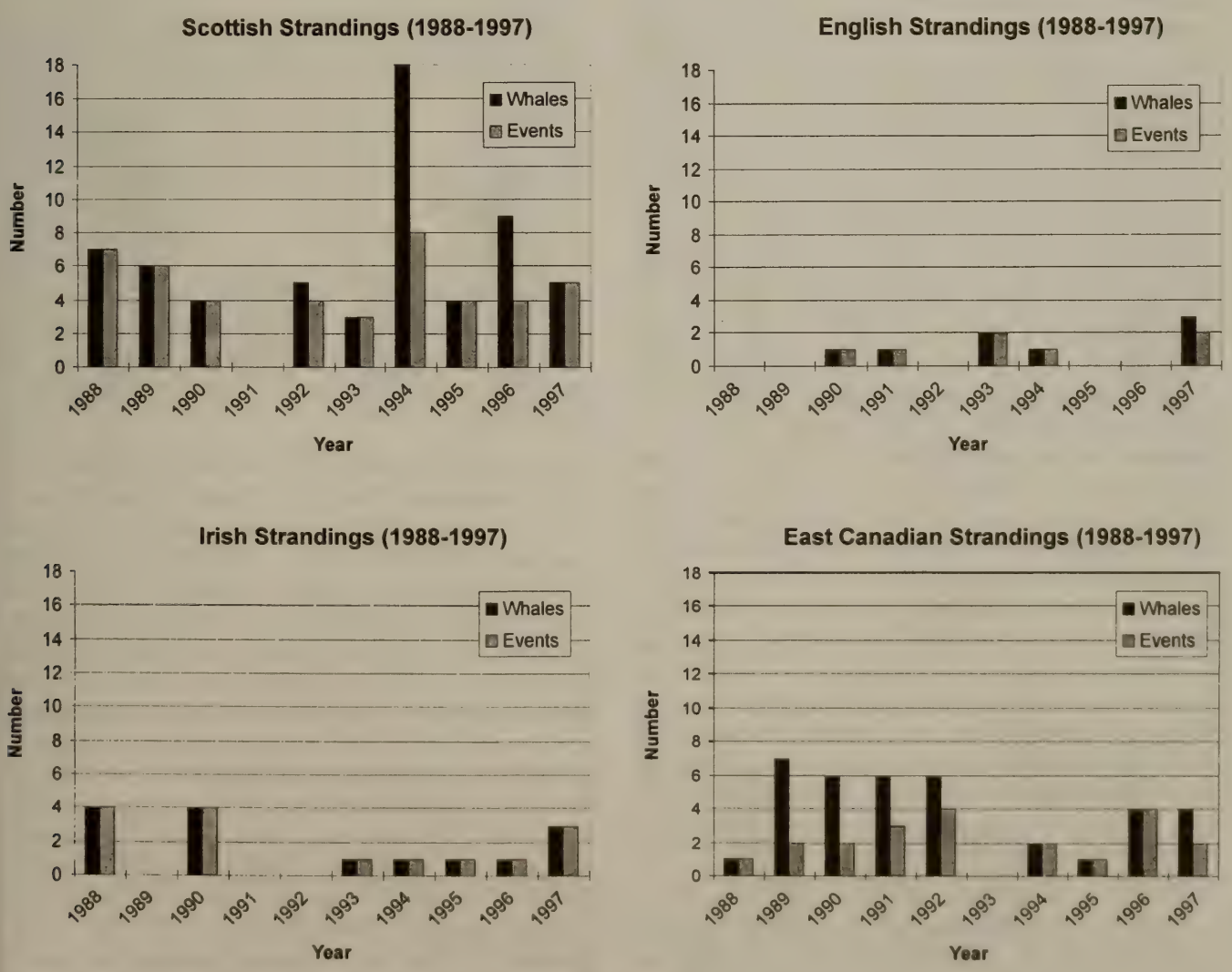


FIGURE 2. Annual Sperm Whale strandings from 1988–1997.

TABLE 2. Seasonality of Sperm Whale strandings from 1988–1997 inclusive

	Scotland		England & Wales		Ireland		Eastern Canada	
Season	Whales	Events	Whales	Events	Whales	Events	Whales	Events
January–March	22	17	1	1	7	7	10	6
April–June	10	10	0	0	3	3	7	6
July–September	9	8	0	0	3	3	6	3
October–December	20	10	7	6	1	1	13	5
TOTAL	61	45	8	7	14	14	36	20

Ireland excludes uncertain 1997 date; Canada excludes 1994 female

remains, however, as to why have there been these increases. Some possibilities are discussed here.

Increases in Reporting

One hypothesis would be that strandings have not increased at all, but that we are seeing an artefact in the data as a result of improved reporting in recent times, perhaps as society becomes more aware of environmental issues and species conservation. If this were indeed the case, one might expect remote outlying regions to have historically been poorly represented in the stranding record, with subsequent increases in reporting as communications and environmental awareness improve. This hypothesis does seem to be consistent with the fact that the remote Scottish islands exhibit a greater rate of increase in strandings than does the mainland, where communications have perhaps been better during recent history. However, strandings still have significant exponential increases on both the mainland and Irish coasts, suggesting that geographical remoteness from a central recording point is not necessarily a deciding factor. Indeed, one may take the opposing viewpoint and argue that Sperm Whales are large animals and their strandings generate sufficient interest to make reporting via some medium or another highly likely in most instances. If increased reporting effort is suspected in recent years, a good control would be to consider the data pre- and post the 1992 onset of the DoE project in Scotland, where an official reporting scheme was put into effect. It has already been demonstrated that no significant trend emerged in the data for the period 1988 to 1997, and inspection of Figure 2 shows no sign of a "surge" in Sperm Whale strandings from 1992. In contrast, strandings of small cetaceans in Scotland show a multi-fold increase at the 1992 project onset. This is just the effect we expect to see with species that are small and less noteworthy of reporting by casual observers. The fact that this does not occur in the Sperm Whale data leads us to suspect that increased reporting is not a major factor in the case of this species.

Increases in Population Size

Taking the north Atlantic as a whole, and discounting effects of differing habitat use, the observed rates of increase in Sperm Whale strandings on Irish and Scottish coasts (0.089/yr and 0.181/yr) far outstrip the potential population growth rate according to IWC models of Sperm Whales (0.008/yr) and the possibly more realistic Killer Whale, *Orcinus orca*, models (0.029/yr) — see Appendix E. Substantial increases in the populations of large males are possible for a few years after sex-biased whaling ends (Figure 7), but they do not appear to last long enough to account for the dramatic trends in Scottish and Irish strandings. Furthermore, if the increase in strandings was solely due to an increase in population size, then strandings might be expected to increase at the same rate throughout the population where large males strand. The discrepancy (two fold) between the rates of increase of strandings on Scottish and Irish coasts, both effectively within the same geographic area, suggests that a population increase is unlikely to be responsible for the observed trends. However, differing habitat use, even across a relatively small geographic area, may account for different stranding densities. Defining habitat use over such small scales requires higher resolution data than is currently available, although recent work suggest the Atlantic Frontier adjacent to the Scottish coasts to be an important region for Sperm Whales (Moscrop and Swift 1999).

Changes in Distribution and Migration Patterns

The temporal changes in British stranding rates could be caused by changes in distribution and migration patterns, but they would have to have been extremely dramatic to fully account for the patterns in the Scottish and Irish strandings. In particular, the waters off Scotland would have had to have changed from an area of very marginal importance before 1975 to a major habitat in the 1990s. Data presented by Evans (1997) are not consistent with this scenario: there were an equal number of sightings of Sperm Whales from the ocean weather ship "Cumulus" 300 km west of Scotland during the periods 1975 to 1984 and 1985 to 1994 (14 each). However, Evans does report an increased preponderance of smaller whales stranding since 1975, suggesting a shift in the population structure with possible immature animals frequenting higher latitudes.

TABLE 3. Sperm Whale strandings within decadal periods from 1908–1997.

	Scotland		England & Wales		Ireland		Eastern Canada	
Year	Whales	Events	Whales	Events	Whales	Events	Whales	Events
1908–1917	≥ 2	≥ 2	≥ 0	≥ 0	1	1		
1918–1927	0	0	0	0	0	0		
1928–1937	0	0	2	2	1	1		
1938–1947	3	3	0	0	2	2		
1948–1957	1	1	0	0	1	1		
1958–1967	1	1	1	1	3	3		
1968–1977	4	4	4	4	4	4	≥ 1	≥ 1
1978–1987	9	9	3	3	6	6	≥ 3	≥ 3
1988–1997	61	45	8	7	15	15	9	4
TOTAL	≥ 81	≥ 65	≥ 18	≥ 17	33	33	≥ 13	≥ 8

Although there have been many stranded animals < 12 m in length on the British coasts since 1975, there continues to be many strandings of animals > 12 m in length; further there have been incidents. of small whale strandings prior to 1975 — where the data are very much more sparse in any case. Figure 8 illustrates the body length data of Sperm Whales stranded on the Scottish, Irish, English and eastern Canadian coasts; the wide range of body lengths in recent times (particularly in the Scottish data) is quite evident. Evans (1997) suggests that younger males may have less incentive to periodically return south to the breeding schools than will the large males, and as a consequence may suffer seasonal food shortages, leading to mortality. Post mortem examinations from recent Scottish strandings

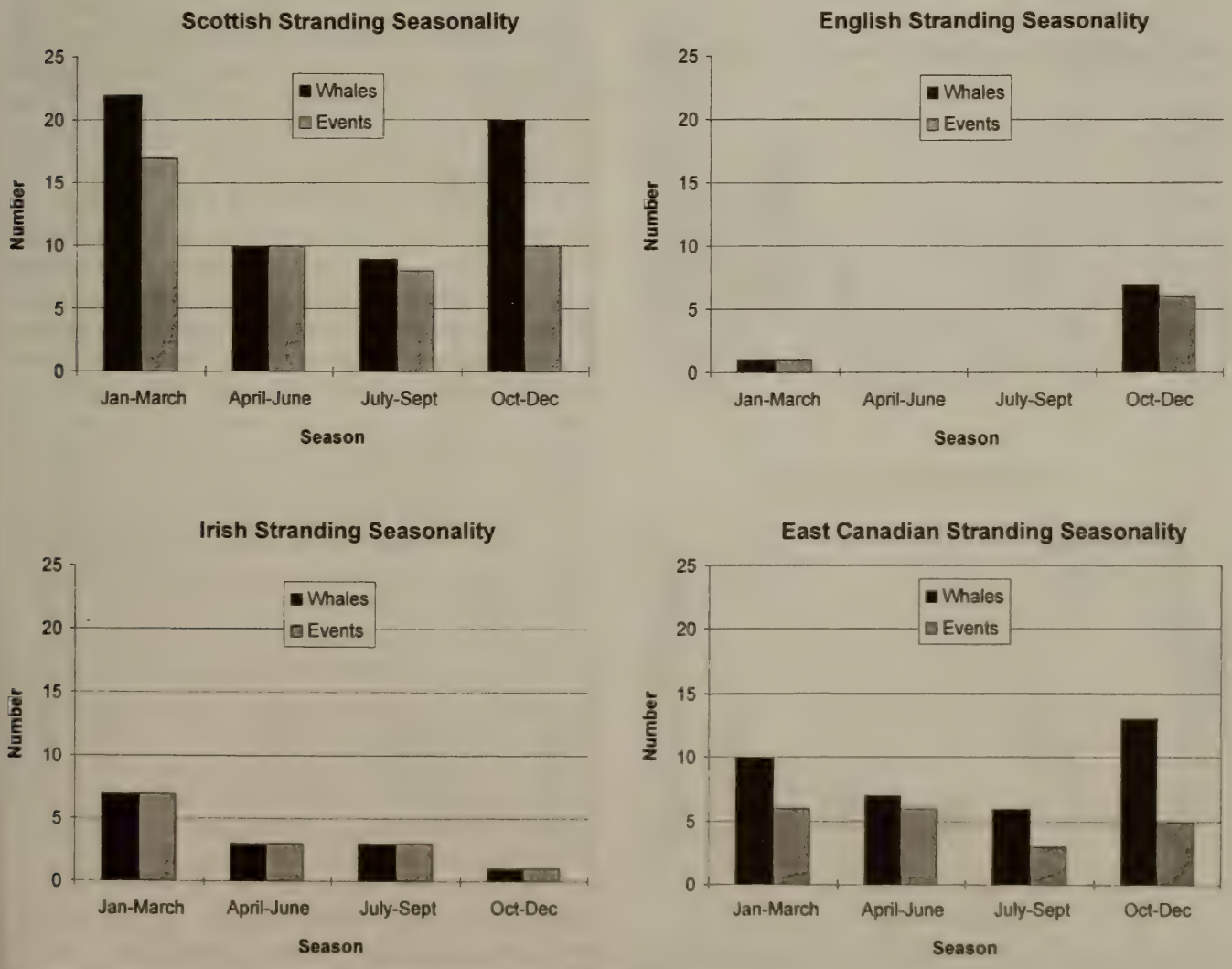
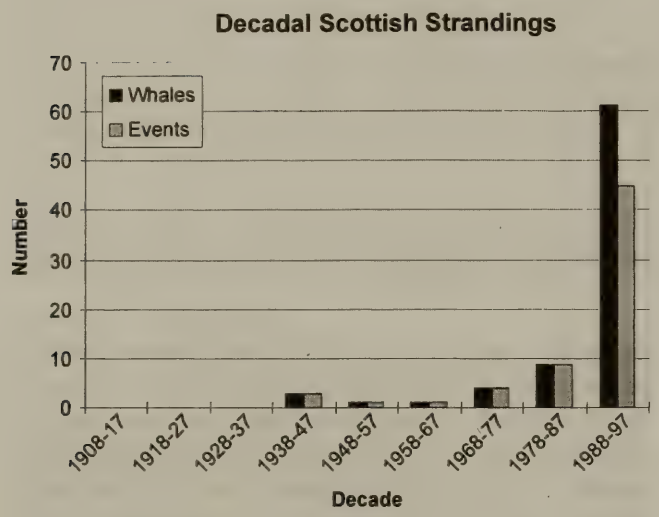
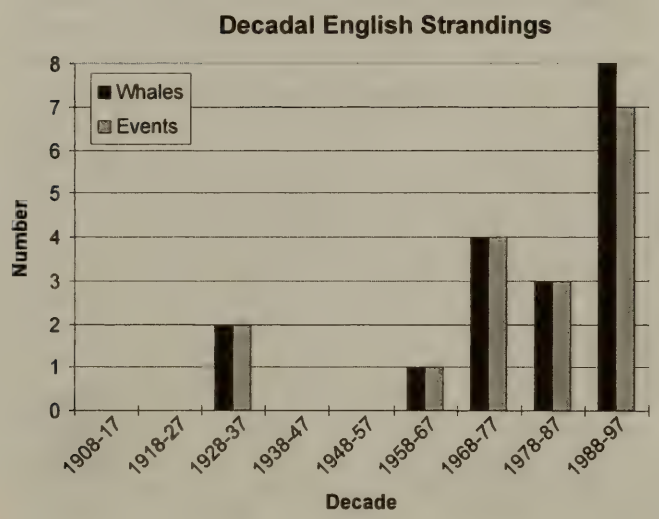


FIGURE 3. Seasonality in Sperm Whale strandings from 1988–1997.

indicate mid-lateral blubber thicknesses of 120 to 140 mm, suggesting that these animals are in a reasonably good nutritive state. Given the continued stranding of males >12 m in length, and the reasonable body condition of many stranded animals, Evans' argument is not entirely convincing.





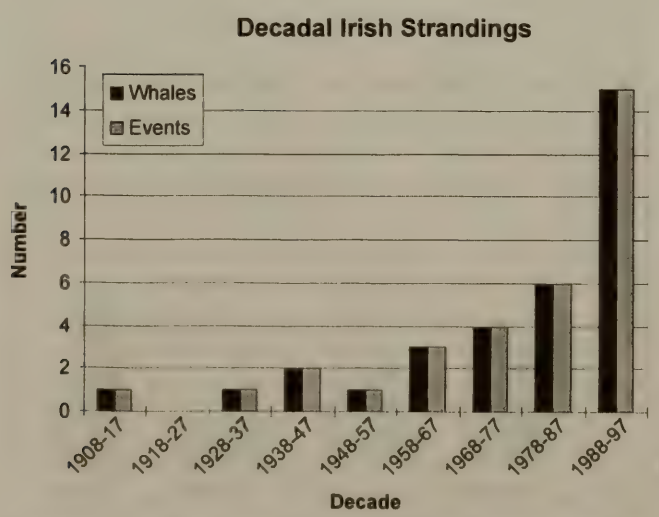


FIGURE 4. Decadal trends in Sperm Whale strandings from 1908–1997.

Increased Mortality

Fisheries By-Catch

Fisheries by-catch is a serious problem around the British coasts for a number of small cetacean species (Kuiken et al. 1994; Kirkwood et al. 1997; Berrow and Rogan 1998). Harbour porpoise are thought to be suffering a population mortality rate of some 6% per year due to bycatch, and many beached carcasses show signs of entanglement in fishing gear. Common dolphin have suffered similar instances of entanglement, with notable mass stranding of carcasses where fishing injury has been involved (Kuiken et al. 1994). Although fisheries and driftnetting has been a serious problem for Sperm Whales in some regions of the world [e.g., the Mediterranean (Di Natale 1990)] there is no gross external evidence from recent post-mortem examinations of British and eastern Canadian stranded Sperm Whales having suffered entanglement in fishing gear. Historical records similarly do not suggest fisheries interaction to be a factor in strandings. We therefore consider the increasing rate of Sperm Whale strandings unrelated to direct fishing injury. Further, the prey species of Sperm Whales are typically dissimilar to those harvested commercially for human consumption (Clarke 1996), so direct conflict with fishery resources also seems unlikely.

Nutrition & Toxic contamination

It is difficult to perform even a basic autopsy in the remote locations where Sperm Whales often strand. Conversely, public health concerns often restrict beach-head autopsies in more populated regions. Information on the health status of stranded Sperm Whales is therefore rather limited. However, stomachs from whales which have been examined, particularly from two mass strandings in Scotland (Santos 1998) generally show evidence of recent feeding, i.e. squid beaks are present — mainly *Gonatus fabricii*. In addition, mid-lateral blubber thicknesses (of some 120 to 140 mm) suggest whales that strand on the Scottish coast to be in a reasonable nutritive state prior to death, tending to weigh against chronic disease as a cause of stranding. These observations contrast with those of recent Sperm Whale strandings on the Belgian and Dutch coasts, where whales had reduced blubber thickness and some had severe weight deficiency (Jauniaux et al. 1997). This may be consistent with the notion of the North Sea (to the east of mainland Britian) acting as a Sperm Whale trap (Smeenk 1997), resulting in starvation as this shallow shelf sea is largely devoid of typical Sperm Whale prey items. However, our data mainly considers strandings on the western coasts of the British Isles, and starvation is not evident.

TABLE 4. British strandings data tabulated as mainland (excluding Ireland) vs. remote islands.

	England + Mainland Scotland		Scottish Islands	
Year	Whales	Events	Whales	Events
1913–1917	2	2	0	0
1918–1927	0	0	0	0
1928–1937	2	2	0	0
1938–1947	0	0	3	3
1948–1957	0	0	1	1
1958–1967	1	1	1	1
1968–1977	4	4	4	4
1978–1987	5	5	7	7
1988–1997	21	15	48	37
Total	35	29	64	53

Considering the North Sea again, Mercury and Cadmium were also found at high levels in Sperm Whales stranded on the Belgian coast (Bouquegneau et al. 1997). Cadmium, although expected due to a cephalopod rich diet, was found at concentrations twice that previously recorded in the literature, and was not bound to metallothioneins (a protein known for its protective effect against heavy metals). Measured chlorobiphenol levels in British stranded Sperm Whales have been shown to be low in comparison with other species of cetacean (Wells et al. 1997). Chemical pollution is therefore a factor for consideration in Sperm Whale strandings generally, but given the relatively good condition of recent whales stranded on the Scottish coast, it is unlikely that toxic contamination is a direct cause of such dramatic increases in strandings as are observed in the data.

Industrial Activites

Other than fishing, which has been considered separately, the anthropogenic activities most likely to impact the deep water environment of the Sperm Whale are shipping traffic, oil and gas exploration, and military activities. Sperm Whales are deep water pelagic predators, feeding primarily on water column species and also some benthic species. Therefore, they are likely to be directly affected by activities that impact on the entire water column in which they live.

All three of the above mentioned activities entail varying degrees of physical and acoustic intrusion into the water column. Considering the case of shipping, the passage of a vessel through the water presents a possible collision hazard to a whale at the surface (Terhune and Verboom 1999). Further, the noise emitted from engines and associated machinery serves to raise the levels of background noise, to which Sperm Whales may or may not be sensitive. Further, raised levels of background noise may progressively mask sounds of importance to sperm whales — e.g., intra-specific communications; biosonar for navigation and food finding; sounds created by other marine organisms. Large powered vessels have been traversing the Atlantic since the beginning of the twentieth century, but the rapid increase in strandings is a relatively recent phenomenon. Although fast vessels present a serious

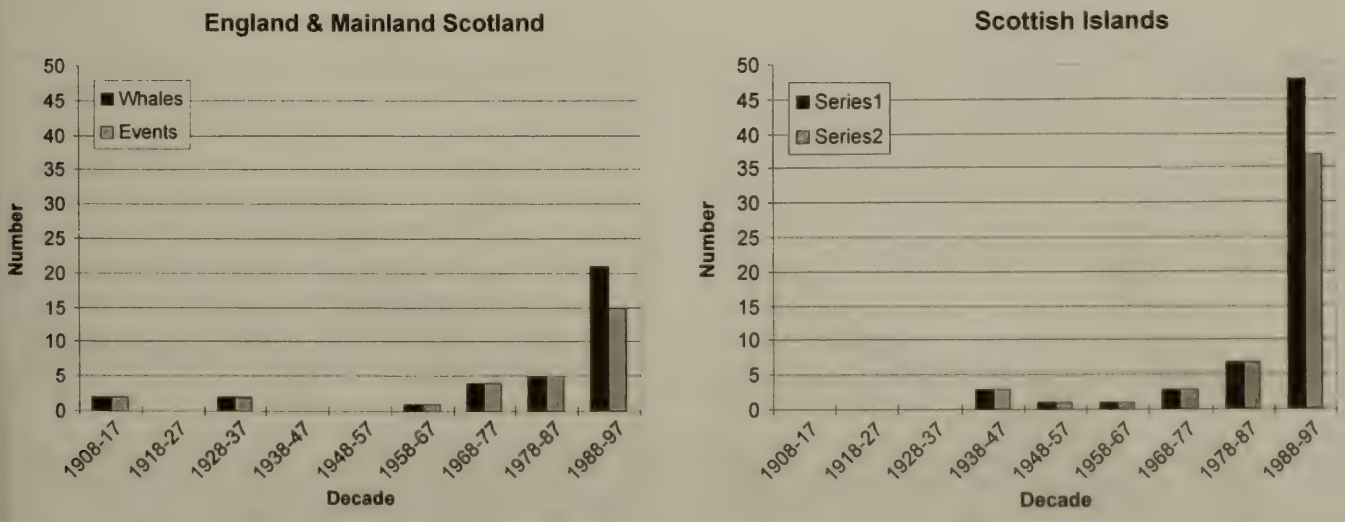


FIGURE 5. Decadal Sperm Whale stranding trends separated into mainland Scotland + England vs. more remote Scottish Islands.

TABLE 5. Parameter estimates for the model of increase in Sperm Whale stranding events by year. Standard errors are indicated in parentheses.

Geographic Area	Basal level [k] /yr	Increase [b] /yr	Start of increase [c]
British Isles	3.1 (1.3)	1.139 (0.019)	1970 (6)
Scotland	1.1 (0.6)	1.180 (0.019)	1971 (5)
Ireland	1.0 (0.5)	1.089 (0.016)	1962 (10)
England	0.2 (0.8)	1.058 (0.027)	1928 (102)
England +Mainland Scotland	0.5 (0.6)	1.105 (0.024)	1960 (17)
Scottish Islands	1.2 (0.6)	1.188 (0.028)	1973 (5)

hazard to Sperm Whales at the surface, and multiple mortalities have resulted from fast ferry strikes in other regions of the world (Aguilar et al. 2000), such vessels do not operate intensively in the regions under consideration here, and there is no evidence of vessel collision from the strandings data.

Oil and gas exploration has been demonstrated in some instances to cause behavioural reactions in large whale species (Richardson et al. 1995), and avoidance of high powered sound sources by Sperm Whales has been documented (Bowles et al. 1994). The type of activity of primary concern is seismic surveying, where loud, concussive type sound pulses are produced by high pressure air-guns beneath the water surface. Seabed sub-bottom profiles are mapped through the process of penetration and reflection of these sound pulses, which are typically received by long trailing hydrophone streamers deployed from seismic vessels. Seismic pulse energy also radiates outwards into the wider water column, essentially ensonifying a large swath of ocean. Behavioural avoidance of these activities has been documented in Bowhead, Gray and Humpback whales (Richardson et al. 1995; Richardson 1998; McCauley 1998, 2000) and there is some evidence that sperm whales may be displaced by such activities (Mate et al. 1994). In addition, there is evidence that seismic pulses also have the potential to cause disturbance to small odontocetes (Goold and Fish 1998), which should be the least vulnerable of all cetaceans to these noises. Seismic surveying has

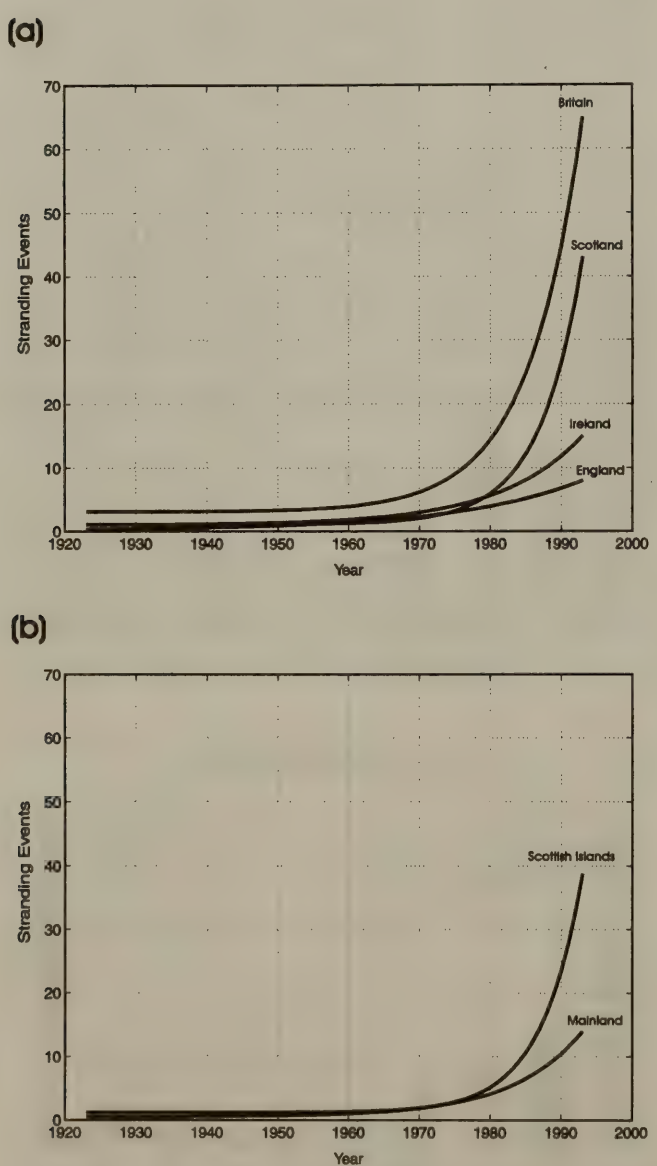


FIGURE 6. Fitted curves of exponential growth showing (a) Sperm Whale stranding trends for Scotland, Ireland, England and the British Isles as a whole; and (b) mainland Scotland+England vs. remote Scottish Islands.

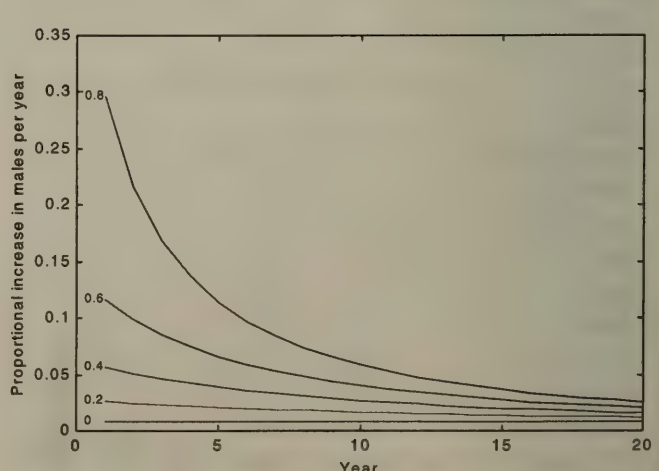


FIGURE 7. Rates of increase of older (>20yr old) males, following the end of exploitation which resulted in the proportion of mature males in the population being artificially reduced by 80%, 60%, 40%, 20% or 0%.

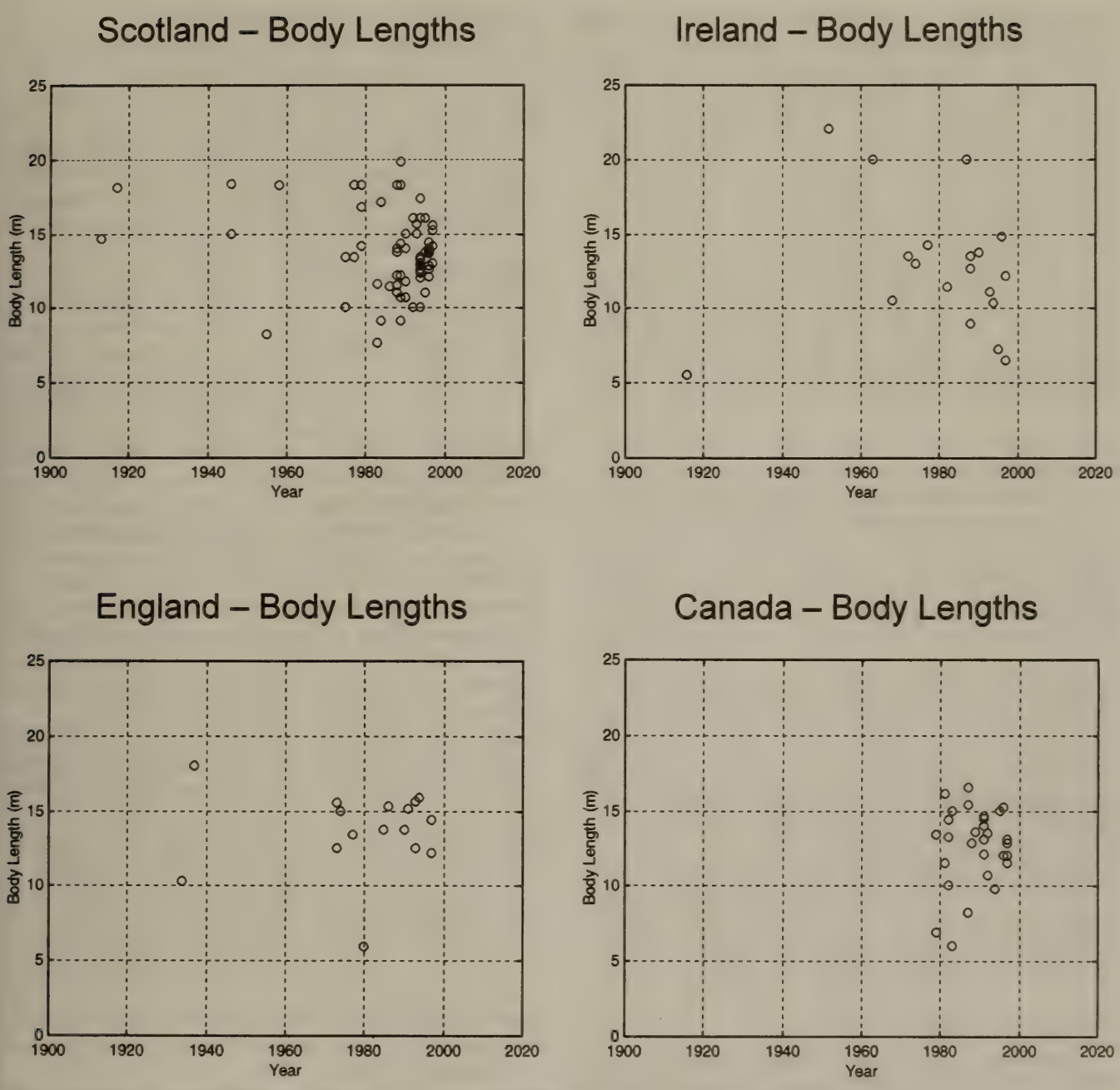


FIGURE 8. Body lengths of Sperm Whales stranded on the British and eastern Canadian coastlines.

been conducted for decades and there are conflicting reports as to its effects on marine wildlife. However, it is notable that extensive deep water seismic surveying took place during the 1990s in the Atlantic Frontier region, to the west of Scotland, approximately adjacent to the remote Scottish Islands where the highest strandings rate has occurred. However, the Scottish Sperm Whale stranding data show peaks during the autumn and winter, whereas seismic operations tend to concentrate during the summer months in the Atlantic Frontier. The same scenario of seasonal mismatching is true for Nova Scotia too. These data, therefore, do not support a hypothesis of cause and effect between strandings and seismic exploration, unless there is some kind of progressive auditory fatigue/damage, resulting in disorientation and a lead time to stranding events. Data on both Sperm Whale abundance and line miles of seismic shooting in either region are too sparse to draw any correlations. Physiological evidence of acoustic trauma in carcasses is also very cryptic, requiring detailed examination of ears and other tissue structures, which is currently beyond the scope of the stranding schemes.

Military Activities

Military activities are by their nature classified, and hence data are very sparse. Potential impacts again include vessel strikes and/or acoustic disturbance by high powered sonar systems and ordnance detonation. However, as with seismic surveying, there is as yet no evidence to suggest that military activities have played a direct role in Sperm Whale

strandings, although there is evidence from other regions of the world that mid-frequency military sonars can cause mass strandings of deep diving whales (Frantzis 1998). The best documented incident was the multiple species strandings in the Bahamas during March 2000. A number of deep diving beaked whales, along with two Minke Whales and a dolphin, stranded alive in a highly atypical manner, but with timing and position highly correlated with naval activity and the deployment of high powered, tactical mid range sonar systems. Post mortem analysis found haemorrhaging in the brain and ear tissue, consistent with acoustically induced trauma (Balcomb and Claridge 2000; NMFS 2001).

Conclusion

There has been a large increase in reported Sperm Whale stranding events on the British coast during the latter half of the twentieth century. Available data suggest that this phenomenon is not mirrored on east Canadian coasts, although the available data are too sparse to lend weight to this suggestion. British strandings have increased most rapidly off the Scottish coast, with most of the increase due to strandings in the outer islands of Hebrides, Orkney and Shetland since about 1973. There is no single satisfactory explanation, but the data do not support the increase in strandings as being a simple result of an increase in population size. Instead, it seems likely that the trend has two or more causes which may be acting synergistically. Valid hypotheses include increased reporting and anthropogenic effects. Cause(s) and effect(s) appear to be manifested in greatest concentration near the Scottish Islands.

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Appendix A: Scottish Strandings Raw Data, 1913–1997

Reference	Date	Sex	Length (m)	Location of Stranding
Harmer (1927)	*18 Dec 1913*		*14.63*	*Fort George, Inverness*
"	*23 May 1917*	*M*	*18.08*	*Latheron, Caithness*
Fraser (1953)	07 Dec 1938			Hebrides
"	Sep? 1946	M	c60ft?	Shetland
"	Oct? 1946	M	14.94	Shetland
Fraser (1974)	30 Jun 1955		8.23	Bay Head, North Uist, Hebrides
"	?? Jun 1958		c18.29	North Roe, Shetland
Scheldrick (1989)	?? Jan 1975	M	10.06	Holm of Boray, Isle of Gairsay, Orkney Islands
"	12 Sep 1975	M	13.41	North Boisdale, South Uist, Outer Hebrides
"	01 Jul 1977	M	13.41	North Boisdale, South Uist, Outer Hebrides
"	20 Nov 1977	M	18.29	Ham Voe, Foula, Shetland Islands
"	28 Feb 1979	M	c18.29	Tinna's Voe, Skeld, Shetland Islands
"	05 Mar 1979	M	16.76	West Gernish, South Uist, Western Isles
"	*22 Aug 1979*	*M*	*14.12*	*Cullen Bay, Grampian*
"	?? Jan 1983	M	c11.58	Flotta Island (S.E.), Weisdale Voe, Shetland
"	?? Jun 1983	M	7.62	Isle of Tiree, Strathclyde
"	?? Jun 1984	M	c9.14	Gortanaoid Point, Islay, Strathclyde
"	13 Dec 1984	M	17.07	Bea Ness, Sanday, Orkney Islands
"	*23 Jan 1985*	*M*		*Crouie, Gardenstown, Grampian*
"	04 Feb 1986		10.67–12.19	Drid Geo (S.Side), Eshaness, Mainland, Shetland
Scheldrick et al. (1994)				
"	27 Feb 1988	M	11.5	Galoson, west coast Isle of Lewis, Western Isles
"	26 Feb 1988	M	13.72	Sanday, Unst, Orkney Islands
"	19 Mar 1988	M	14	Bay of Newark, Orkney Islands
"	*24 Mar 1988*	*M*	*18.29*	*Lendalfoot, (nr Girvan) Strathclyde*
"	25 Mar 1988		12.19	Garrynamonie, South Uist, Western Isles
"	07 Jul 1988	M		Bressay, Shetland Isles
"	29 Nov 1988	M	11	Bow Head, Westray, Orkney Islands
"	22 Feb 1989		18.3–21.3	Culswick West, Shetland Isles
"	16 May 1989		9.14	Isle of Eigg, Highland
"	15 Jun 1989	M	12.19	The Ness, North Mainland, Shetland Isles
"	27 Jul 1989	M	14.33	North Beach, Haroldswick, Unst, Shetland Isles
"	01 Aug 1989	M	10.67	Heagan Beach, West Burrafirth, Shetland Isles
"	02 Aug 1989	M	18.29	Stoney Bridge, South Uist, Western Isles
"	*01 Feb 1990*	*M*	*14.94*	*The Bar, Culbin Forest, Findhorn, Grampian*
"	23 Feb 1990	M	14.02	Daliburgh, South Uist, Western Isles
"	04 Apr 1990		10.67	Cragaig, Isle of Ulva, Strathclyde
"	04 Apr 1990	M	11.8	Rubh An T Subhein, (nr Rendle) Isle of Mull
"	29 May 1992	M	c 16	Fuday, Barra, Western Isles
"	20 Jul 1992	M		Monach Isles, Western Isles
"	20 Jul 1992			Monach Isles, Western Isles
"	04 Dec 1992	M	c 10	Sanday, Orkney Islands
"	22 Dec 1992			Northton, Harris, Western Isles
Reid	*21 Jul 1993*			*The Burr, Eshaness*
"	*21 Nov 1993*	*M*	*15*	*Lochailort, Highland**
"	24 Nov 1993	M	15.65	Loch Ainort, Skye*
"	13 Mar 1994	M	13	Hougharry, North Uist, Western Isles
"	13 Mar 1994	M	17.37	Ayre of Birrier, Yell, Shetland Isles
"	27 Mar 1994	M	16	Campa Islay, Argyll
"	09 Apr 1994		c16	Sound of Berneray, Western Isles
"	24 Apr 1994	M	c10	St. Ninians Isle, Shetland
"	30 May 1994		c12	Floating off Balta, Shetland
"	*18 Aug 1994*			*Swordle, Ardnamurchan, Highland*
"	07 Dec 1994	M	12.4	Backaskail Bay, Sanday, Orkney Islands*
"	07 Dec 1994	M	12.3	Backaskail Bay, Sanday, Orkney Islands*
"	07 Dec 1994	M	12.8	Backaskail Bay, Sanday, Orkney Islands*
"	07 Dec 1994	M	12.8	Backaskail Bay, Sanday, Orkney Islands*
"	07 Dec 1994	M	13.2	Backaskail Bay, Sanday, Orkney Islands*
"	07 Dec 1994	M	12.6	Backaskail Bay, Sanday, Orkney Islands*
"	07 Dec 1994	M	12	Backaskail Bay, Sanday, Orkney Islands*

continued

Appendix A: ***continued***

Reference	Date	Sex	Length (m)	Location of Stranding
"	07 Dec 1994	M	13.3	Backaskail Bay, Sanday, Orkney Islands*
"	07 Dec 1994	M	12.4	Backaskail Bay, Sanday, Orkney Islands*
"	07 Dec 1994	M	12.5	Backaskail Bay, Sanday, Orkney Islands*
"	07 Dec 1994	M	13.4	Backaskail Bay, Sanday, Orkney Islands*
"	19 Jan 1995	M	c16	Brenish Beach, Lewis, Western Isles
"	27 Jan 1995	M	c14	Culla Beach, Benbecula, Western Isles
"	*23 Mar 1995*	*M*	*13.7*	*Nr Carse of Ardersier, Highland**
"	09 Apr 1995		c11	Creag Loisgte, Islay, Strathclyde
"	*28 Jan 1996*	*M*	*13.65*	*Cruden Bay, Grampian**
"	*28 Jan 1996*	*M*	*13.65*	*Cruden Bay, Grampian**
"	*28 Jan 1996*	*M*	*12.6*	*Cruden Bay, Grampian**
"	*28 Jan 1996*	*M*	*13.75*	*Cruden Bay, Grampian**
"	*28 Jan 1996*	*M*	*12.1*	*Cruden Bay, Grampian**
"	*28 Jan 1996*	*M*	*12.85*	*Cruden Bay, Grampian**
"	08 Sep 1996			LargeIsland of Mousa, Shetland
"	27 Dec 1996	M	14.4	Traigh Angus, Islay, Strathclyde
"	31 Dec 1996		c13.9	Sand, West Mainland, Shetland
"	28 Mar 1997		c13	Goile Chroic, Lewis, Western Isles
"	*31 Mar 1997*	*M*	*15.2*	*Airth, Central**
"	07 Apr 1997		c13	Papa Stronsay, Orkney Islands
"	20 Nov 1997	M	14.17	Stornoway Airport, Western Isles*
"	27 Nov 1997	M	15.54	Melbost, Western Isles*

Italics = mainland strandings
* = strandings in which animals are known to have come ashore alive

Appendix B: England and Wales Raw Data, 1913–1997

Reference	Date	Sex	Length (m)	Location of Stranding
Fraser (1946)	18 Jan 1934	M	10.29	Kimmeridge, Dorset
"	25 Jan 1937	M	18	Bridlington, Yorkshire
Sheldrick (1989)	?? Nov 1967			Samson, Isles of Scilly, Cornwall
"	07 Feb 1973		15.54	Portreach, Cornwall
"	06 Oct 1973	M	c41ft	Seaton Point, Boulmer, Northumberland
"	19 Jan 1974	M	14.94	Skidbrooke, Lincolnshire
"	18 Nov 1977	M	13.41	Boule Bay, N.coast Jersey, Channel Isles
"	17 Sep 1980		5.94	Marazion, Cornwall
"	01 Mar 1985		40–50ft	Skegness, south of Lincolnshire
"	30 Nov 1986	M	15.32	Holcombe Beach, Wells, Norfolk
Sheldrick et al. (1994)	09 Feb 1990	M	13.72	Long Rock Beach, Marazion, Cornwall
"	12 Nov 1991	M	15.1	Brancaster, Norfolk
Muir	02 Dec 1993		12.5	Hunstanton, Norfolk
"	15 Dec 1993	M	15.6	Atwick, Humberside
"	10 Nov 1994	M	c15.85	Hawkster Bottoms, nr Whitby, North Yorkshire
"	03 Dec 1997	M	14.4	Skegness, Lincolnshire
"	03 Dec 1997	M	c12.19	Trinity Sand, Humber Estuary
"	03 Dec 1997	M	c12.19	Trinity Sand, Humber Estuary

Appendix C: Irish Strandings Raw Data, 1901–1997

Reference	Date	Sex	Length (m)	Location of Stranding
Berrow and Rogan (1997)	04 Sep 1916		5.49	Roundstone, Galway
"	15 Jul 1936	M		Lislary, Sligo
"	18 Nov 1939			Kilkee, Clare
"	?? ??? 1943			Louisberg, Mayo (L7477)
"	02 Jan 1952	M	22	Derryloughan, Galway
"	25 Jul 1963	M	20	Rosbeg, Donegal
"	?? ??? 1967			Bertraghboy Bay, Galway (L7437)
"	21 Mar 1967	M		Achill Isle, Mayo
"	?? Dec 1968		c9–12	Crookhaven, Cork
"	20 May 1972		c12–15	Buncrana, Donegal
"	30 Nov 1974	M	13	Portrush, Antrim (C8541)
"	09 Jul 1977	M	14.2	Sligo (G6139)
"	13 Oct 1978			Kerry (Q7424)
"	?? Jan 1980			Rathlin Isl. Antrim (D1050)
"	?? Sep 1980			Bantry Bay, Cork (V8241)
"	?? Jul 1982		10.7–12.2	Kerry (V3298)
"	08 May 1987			Maglilligan St., Co. Londonderry (C6738)
"	01 Jan 1987	M	20	Kerry (V4898)
"	19 Mar 1988	M	12.65	Clare (R0381)
"	13 Apr 1988	M		Mayo
"	15 Jun 1988	M	9	Mayo (G1141)
"	09 Aug 1988	M	13.5	Sligo (G5941)
"	07 Feb 1990	M	13.7	Mulranny, Mayo (L8296)
"	16 Mar 1990	M		Carrickfin, Donegal (B7923)
"	30 Mar 1990	M		Portscaman, Donegal (C4156)
"	10 Oct 1990			Minard, Kerry (Q5298)
Mallarney and Smiddy (unpublished)	26 Sep 1993	F	11.07	Kilmore Quay, Co. Wexford (S9603)
Berrow and Rogan (1997)	16 Feb 1994	M	10.4	Inverin, Co. Galway (M0521)
Berrow and Rogan (1997)	15 Jun 1995	F	7.22	Youghal, Co. Cork (C0874)
Gassner and Gatins (unpublished)	29 Mar 1996	M	14.8	Tory Island, Co. Donegal (B8546)
Kennedy (in press)	?? Mar 1997	M	c40ft	Maghery, Co. Donegal (B7110)
IWDG	20 Sep 1997		c40ft	Oranmore, Co. Galway (M3824)
Strong	Sept/Oct 1997		6~7	Blacksod, Co. Mayo (F6418)

Appendix D: Eastern Canadian Strandings Raw Data: ~1987–1997 (with Sable Island from 1970–1997)

Reference	Date	Sex	Length (m)	Location of Stranding
Lucas and Hooker (2000)	?? Apr 1977			Sable Island, Nova Scotia
Lien (personal communication)	8 Jun 1979	F	13.4	Burnside, Bonavista Bay, Newfoundland/Labrador
"	31 Aug 1979	M	6.9	Portugal Cove, Conception Bay, Newfoundland/Labrador
"	14 Aug 1981	M	16.1	Reefs Harbour, Newfoundland/Labrador
"	5 Oct 1981	M	11.5	Nain, Newfoundland/Labrador
"	10 Apr 1982	M	10.0	Lords Cove, Newfoundland/Labrador
"	28 Apr 1982	M	14.4	Point May, Newfoundland/Labrador
"	29 Jun 1982	M	13.2	Cartwright, Newfoundland/Labrador
"	25 Jul 1983	M	15.0	Hare Harbour, Newfoundland/Labrador

continued

Appendix D: ***continued***

Reference	Date	Sex	Length (m)	Location of Stranding
Lucas and Hooker (2000)	?? Jul 1983		>6.0	Sable Island, Nova Scotia
"	?? Feb 1984	M		Sable Island, Nova Scotia
"	?? Mar 1987	M	16.5	Sable Island, Nova Scotia
Reeves and Whitehead (1997)	11 Jun 1987	M	15.4	Red Harbour, Placentia Bay, Newfoundland/Labrador
"	08 Jul 1987	M	8.2	Penguin Island West, South Coast, Newfoundland/Labrador
"	13 Dec 1988		12.8	Near Nail Pond, N.W., Prince Edward Island
Lien (personal communication)	01 Mar 1989	M		Conception Harbour, Conception Bay, Newfoundland/Labrador
Reeves and Whitehead (1997)	01 Oct 1989	M	13.6	Covehead Harbour, N., Prince Edward Island*
"	01 Oct 1989	M		Covehead Harbour, N., Prince Edward Island*
"	01 Oct 1989	M		Covehead Harbour, N., Prince Edward Island*
"	01 Oct 1989	M		Covehead Harbour, N., Prince Edward Island*
"	01 Oct 1989	M		Covehead Harbour, N., Prince Edward Island*
"	01 Oct 1989	M		Covehead Harbour, N., Prince Edward Island*
"	30 Sep 1990			Black Tickle, Labrador*
"	30 Sep 1990			Black Tickle, Labrador*
"	30 Sep 1990			Black Tickle, Labrador*
"	30 Sep 1990			Black Tickle, Labrador*
"	06 Oct 1990	M		Sable Island, Nova Scotia
"	06 Oct 1990	M		Sable Island, Nova Scotia
"	15 Jan 1991	M	14.0	Port aux Choix, West Coast, Newfoundland/Labrador
"	25 Apr 1991	M	14.5	Isle Petitgras, Cape Breton Island, Nova Scotia
"	25 Apr 1991	M	14.6	Isle Petitgras, Cape Breton Island, Nova Scotia
"	19 Dec 1991	M		North Rustico, N., Prince Edward Island
"	20 Dec 1991	M	12.1	Brackley Beach, N., Prince Edward Island
"	23 Dec 1991	M	13.1	Brackley Beach, Prince Edward Island
"	17 Jan 1992	M		Sable Island, Nova Scotia
"	17 Jan 1992	M		Sable Island, Nova Scotia
"	17 Jan 1992	M		Sable Island, Nova Scotia
Lucas and Hooker (2000)	?? Mar 1992	M		Sable Island, Nova Scotia
Reeves and Whitehead (1997)	13 Jun 1992	M	13.5	Port Meunier, Anticosti Island, Quebec
"	24 Jun 1992	M	10.7	Sheldrake 50°15′N, 64°54′W, Quebec
"	?? Jul 1994	F	9.8	Cherry Hill, S. Shore, Nova Scotia
"	?? Dec 1994			River John, N. Coast, Nova Scotia
"	06 Mar 1995	M	15	Lord's Cove, Burin Peninsula, Newfoundland/Labrador
Lien (personal communication)	10 May 1996	M		Burgeo, Newfoundland/Labrador
Whitehead (unpublished)	?? Jun 1996	M	c15	N.W. Miquelon, St. Pierre et Miquelon
Lien (personal communication)	3 Jul 1996	M	12.0	Grand Bank, Newfoundland/Labrador
"	20 Jul 1996	M	15.2	Burgeo, Newfoundland/Labrador
Lucas and Hooker (2000)	13 Jan 1997	M	12.8	Sable Island, Nova Scotia*
"	13 Jan 1997	M	13.1	Sable Island, Nova Scotia*
"	13 Jan 1997	M	11.55	Sable Island, Nova Scotia*
Lien (personal communication)	17 July 1997	M	12.0	Grand Beach, Fortune Bay, Newfoundland/Labrador

*strandings in which animals are known to have come ashore alive

Excludes 5 and 6 October 1989 Prince Edward Island Strandings, as probably included in 1 October total

Appendix E. Potential Rates of Sperm Whale Population Increase

Using the most recent set of Sperm Whale population parameters agreed to by the Scientific Committee of the International Whaling Commission (age of first birth of female = 11 yr; maximum birth rate of mature females = 0.25 /yr; mortality of females = 0.055 /yr; mortality of males = 0.066 /yr; mortality of juveniles = 0.0926 /yr; equal sex ratio at birth; International Whaling Commission, 1982) Sperm Whale populations with a stable age distribution can increase at a maximal rate of 0.0082 /yr (Whitehead 1995). The IWC Sperm Whale model parameters are not especially reliable (Christal 1998). For instance, fecundity rates of female Sperm Whales seem to be age-specific (Best et al., 1984), and assumed mortality rates seem high for adults, and low for juveniles, when compared with those estimated more recently for other odontocete populations (e.g. Olesiuk et al. 1990). The most reliable life history parameters available for any large odontocete are those for the Killer Whales off Vancouver Island (Olesiuk et al. 1990). These animals have a maximum potential rate of increase of 0.029 /yr with a stable age distribution, and this may be a better estimate for Sperm Whales than the 0.0082 /yr calculated from the assumed Sperm Whale population parameters (Christal 1998), although as Killer Whales prey on Sperm Whales, but Killer Whales themselves have few if any natural predators, the sperm whale rate may be somewhat lower.

Recent sperm whaling has concentrated on large males, altering the sex ratio. Thus it is likely that proportions of large males were artificially low when whaling ceased. This means that, following the end of whaling, the population of large males can increase more quickly than that of the females for some years while the sex ratio is imbalanced. This is shown in Figure 8 for rates of increase of populations of large males ($\geq$20 yrs old), whose representation in the population had been artificially decreased, using the population parameters of the IWC (as given above) and assuming stable age distributions of females and young males. For 5–10 years following artificial reduction of the sex ratio, the population of mature males can increase at rates above 0.05 /yr, but over longer periods the effect is small (Figure 7).

Bat Night Roost at an Abandoned Mine in Western Maryland

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Agosta, Salvatore J., Kellie M. Kuhn, and David Morton. 2002. Bat night roost at an abandoned mine in western Maryland. Canadian Field-Naturalist 116(3): 389–392.

Few published records of night roosts used by bats in eastern North America exist. We describe seasonal use and species composition at an abandoned mine used as a night roost by bats in western Maryland. A total of 81 bats from five species were captured from July to September 1999 and March to September 2000. Big Brown Bats (*Eptesicus fuscus*) used the mine regularly and were the most abundant species captured. Capture success (number of bats / trap hour) was positively correlated with nightly ambient temperature, but not correlated with relative humidity.

Key Words: bats, night roost, mine, *Eptesicus fuscus, Pipistrellus subflavus, Myotis lucifugus, Myotis leibii, Lasiurus borealis*, Maryland.

Temperate-zone bats roost in a variety of structures, each important for survival and reproductive success (Kunz 1982). In addition to maternity roosts, summer day roosts, and winter hibernacula, many bats use night roosts in close proximity to foraging areas (Hirshfeld et al. 1977; O'Shea and Vaughan 1977; Kunz 1982; Lewis 1994; Perlmeter 1996; Pierson et al. 1996; Adam and Hayes 2000). For temperate-zone bats, night roosts probably function primarily as resting places that facilitate digestion between nightly foraging bouts (Hirshfeld et al. 1977; Pierson et al. 1996). Although temperate bats spend a high proportion of time in night roosts (e.g., Anthony et al. 1981; Barclay 1982), information on night roost location, activity patterns and species composition is sparse (Adam and Hayes 2000).

Recent studies in Oregon (Perlmeter 1996; Adam and Hayes 2000) and California (Pierson et al. 1996) have drawn attention to the importance of man-made structures as night roosts for a variety of species of bats. These studies have emphasized the need for further investigation into night-roosting behavior and night roost selection. Other than a study on the night-roosting behavior of Little Brown Bats (*Myotis lucifugus*) in an abandoned New Hampshire barn (Anthony et al. 1981), few definitive records of bat night roosts in eastern North America exist. In this paper we report data on the species composition and seasonal use of an abandoned mine used as a night roost by bats in western Maryland. To our knowledge, this is the first record of a site used specifically as a night roost by bats in Maryland.

Methods

We studied night roost use by bats at Round Top Mountain (RTM) located along the Potomac River, 5.4 km southwest of Hancock, Washington County, Maryland (39°N, 78°W). Previous work at a series of abandoned mine tunnels at RTM (Gates et al. 1984; Marsh 1998; D. Feller, personal communication) indicated that these mines serve as important winter and summer habitat for a number of species of bats. Consequently, access to the mines was restricted with gates in 1998 (D. Keech, personal communication). As part of a larger study (Agosta 2001) on the feeding ecology of the Big Brown Bat (*Eptesicus fuscus*), we mist-netted the entrance of RTM mine Number 3 once every 7–10 days from July to September 1999, and from March to September 2000. Mist nets were always opened about 30 min after sunset. Nets were left open for an average of 3.7 ± 0.9 h (n = 28 nights of trapping), excluding one night when nets were closed after 45 min because of rain. Captured bats were held in styrofoam cups with perforated lids until the end of each trapping period to eliminate the possibility of recapture.

To examine possible environmental factors that could influence bat use of the night roost we measured nightly ambient temperature and relative humidity throughout the 2000 study period. Ambient temperature was measured along the forest access road adjacent to the mine three times each night (on the hour, beginning approximately at sunset) with a pocket thermometer. Relative humidity was measured simultaneously with a wet bulb-dry bulb sling psychrometer.

Results and Discussion

To determine if bats roosted in the mine during daytime, we always watched the mine entrance for activity beginning 1 h before sunset until it was too dark to observe. Although bats were regularly caught

TABLE 1. Sex composition, age structure and capture times for bats caught at the abandoned mine in 1999 and 2000.

Species	n				Capture time (minutes after sunset)	
	Male	Female	Juvenile[a]	?	Range	Mean ± SD
Eptesicus fuscus	33	6	2	6	55–323	178.2 ± 57.7
Pipistrellus subflavus	13	3	1	6	124–343	238.2 ± 61.4
Myotis lucifugus	3	1	1	4	70–294	210.5 ± 81.1
Myotis leibii	1				318	
Lasiurus borealis	1				213	

[a]all juveniles were males caught in August 2000

at the mine entrance, we never observed bats exiting the roost for their first foraging bout on any nights in 1999 (n = 6) or 2000 (n = 22). In addition, no bats were seen roosting on two daytime trips into the relatively shallow mine (< 50 m in length). For each species, capture times were consistent with arrival at the mine following the first foraging bout (Table 1). Finally, we observed numerous bats avoiding our net and entering the mine during periods when other bats were captured. Taken together, these observations indicated that mine Number 3 was used exclusively as a night roost.

A total of 81 bats from five species were captured at the mine entrance (1999, n = 17; 2000, n = 64; Table 1). These included the Big Brown Bat (1999, n = 11; 2000, n = 36), Eastern Pipistrelle (*Pipistrellus subflavus*: 1999, n = 2; 2000, n = 21), Little Brown Bat (1999, n = 4; 2000, n = 5), Small-footed Bat (*M. leibii*: 2000, n = 1) and Red Bat (*Lasiuris borealis*: 2000, n = 1). The majority (n = 50; 77%) of bats identified in both years combined were adult, non-scrotal males (Table 1). Eleven nonreproductive adult females were also captured, and the sex of 16 bats was not determined. Since we did not band the bats, it is possible that some individuals were captured repeatedly throughout the study. Marsh (1998) banded 430 bats captured in the summers of 1995 and 1996 at a cave in western Maryland and observed very low recapture success (2.8%). Nonetheless, we were not able to determine if different nights with a single capture represented the same bat or several different bats over the study period. The maximum number of Big Brown Bats, Eastern Pipistrelles, and Little Brown Bats captured on a given night was 6, 12, and 2, respectively.

Although the number of bats using the mine was small (however, we note that we observed more bats than were actually captured avoiding our net and flying into the mine on most nights), interspecific seasonal variation in the use of the night roost was evident in 2000 (Figure 1). No bats were captured on two occasions in spring 2000 (4 April, 5 May), likely because the weather was cold and rainy. The mine was used fairly regularly from early-spring to late-summer by a small population of Big Brown Bats. This was expected because this species forages nightly along the access road and forest clearing adjacent to the mine. The Eastern Pipistrelle was the second most abundant species captured; it exhibited a distinct seasonal use of the mine. Individuals were caught sporadically until late August when 12 Pipistrelles were captured in one night. Many Pipistrelles (more than were actually captured) were observed throughout the night flying around the entrance of the mine. This is consistent with the "swarming" behavior described by Mumford and Whitaker (1975), and may reflect the return of a resident hibernating population to the area. A small number of Little Brown Bats also used the mine sporadically. Small numbers (< 5) of each of these three species have been recorded hibernating in this mine in previous years (D. Feller, personal communication), and it is possible that individuals captured in our study (especially the later part of the study period) subsequently hibernated in the mine.

Although each was represented by a single individual, the presence of the Small-footed Bat and Red Bat at the mine is notable. Little is known about the roosting habits of Small-footed Bats in the region (Merritt 1987), and the species is listed as threatened in Pennsylvania (Kirkland and Krim 1990). Small-footed Bats are thought to roost deep in rock crevices (Merritt 1987) and are easily overlooked during census (D. Feller, personal communication). Numerous drill holes and crevices in the mines at RTM provide adequate hibernacula for Small-footed Bats (S. J. Agosta, personal observation). The Small-footed Bat we captured on 9 September suggests that mines also may be used as night roosts by this elusive species. The capture of a Red Bat in August is also of interest because this tree-roosting species rarely uses caves or mines (Merritt 1987); our study site was well-forested and appeared to provide adequate tree-roosting opportunities. Mumford and Whitaker (1975) captured seven Red Bats in July–September at the entrance of a cave in Indiana. It is unknown why Red Bats occasionally use caves and mines, but it appears to occur most often in late summer (Webster et al. 1985).

For all species combined, nightly capture success (number of bats captured / trap h) at the mine was not correlated with relative humidity (Spearman rank, $r = 0.30$, $P > 0.05$), but was positively correlat-

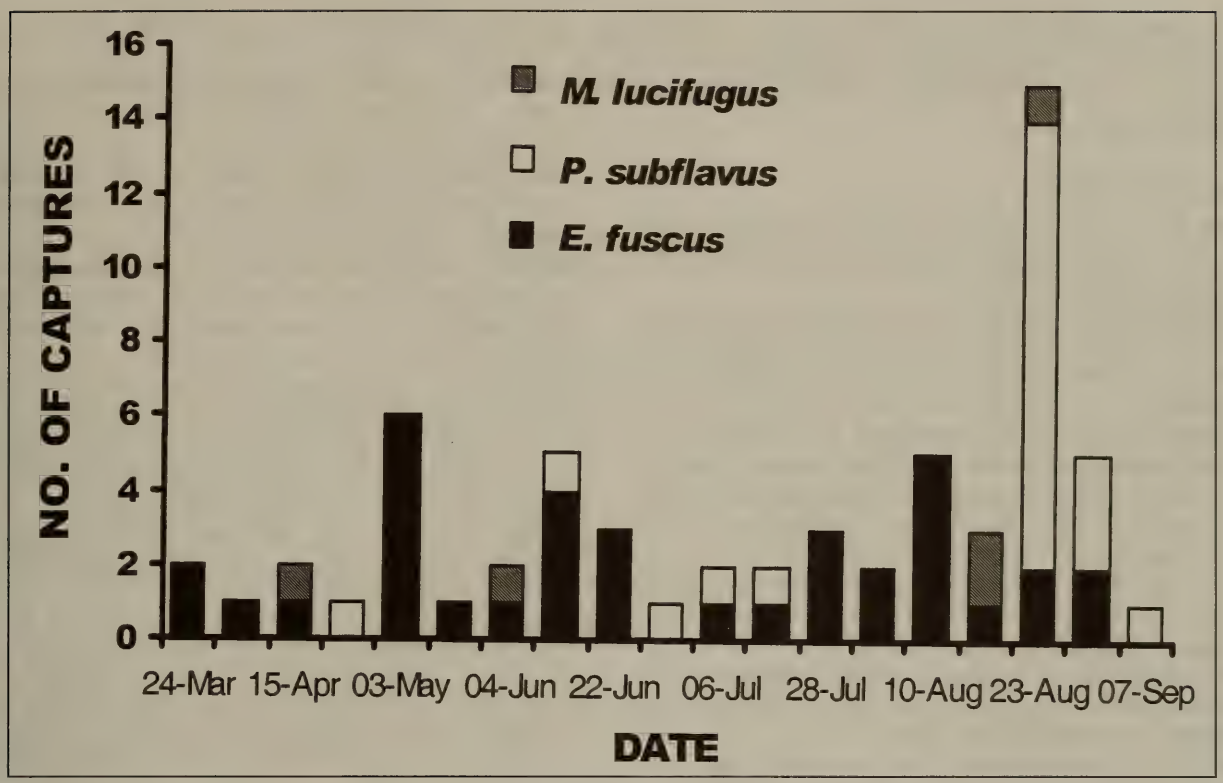

FIGURE 1. Seasonal use of an abandoned mine used as a night roost by three species of bats in western Maryland during the 2000 foraging season.

ed with ambient temperature ($r = 0.70$, $P < 0.05$; Figure 2). Many studies have reported a positive relationship between bat foraging activity and ambient temperature (e.g., Lacki 1984; Hayes 1997; Gaisler et al. 1998). Anthony et al. (1981) found an inverse relationship between ambient temperature and the length of night-roosting bouts by female Little Brown Bats, and a positive relationship between ambient temperature and total insect density. These data indicate that foraging activity by Little Brown Bats decreases at low temperatures when foraging conditions are poor. In our study, it is possible that the relationship between capture success at the night roost and ambient temperature reflected different levels of foraging activity in response to variable insect densities (i.e., many bats remained in day roosts at low temperatures). Our limited data also support the findings of Grinevitch et al. (1995) that male and nonreproductive female Big Brown Bats do not forage at ambient temperatures < ~12°C (Figure 2).

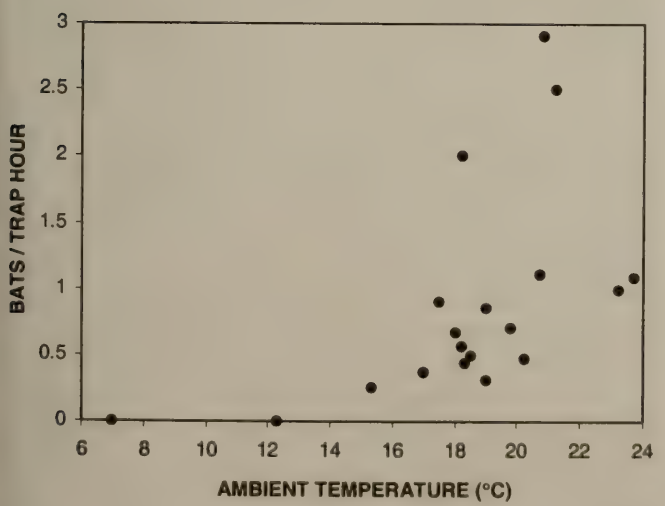

FIGURE 2. Relationship between capture success (number of bats / trap hour) at the abandoned mine night roost and ambient temperature on 19 nights from 4 April to 7 September 2002. Ambient temperature represents the average of three nightly measurements.

More work is needed on the night-roosting behavior of temperate-zone bats (Adam and Hayes 2000). In many areas, night roosts need to be located and documented for this research to progress. Although the data presented here were collected from a single mine, we emphasize the potential value of abandoned mines to bats, and efforts to salvage and protect these structures should continue or be initiated (see Pierson 1998). The data presented here suggest that abandoned mines may be important resting-places for foraging bats in western Maryland; however, more data are needed to assess their potential significance.

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Relative Abundance, Habitat Use, and Breeding Status of Birds in Aulavik National Park, Banks Island, Northwest Territories

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During the summers of 1995 and 1996, we inventoried bird populations of Aulavik National Park (73°N, 119°W), located on northern Banks Island in Canada's Arctic Archipelago. Our study added four new species, bringing the total of bird species to 44 for Aulavik and 74 for Banks Island as a whole. We also documented 21 new breeding records in the park, and the known breeding distribution of Semipalmated Plover (*Calidris pusilla*), Purple Sandpiper (*Calidris maritima*) and Buff-breasted Sandpiper (*Tryngites subruficollis*) were extended. Point-counts were carried out in three different study areas of the park and used to determine relative abundance for 13 species. Lapland Longspur (*Calcarius lapponicus*) was the most common species. Lapland Longspurs, Horned Larks (*Eremophilia alpestris*), Glaucous Gulls (*Larus hyperboreus*), and Black-bellied Plovers (*Pluvialis squatarola*) were significantly associated with a few different habitat types. No habitat type had notably more bird species as compared to the other types, with the exception of sparsely vegetated ground which supported fewer species. Field observations, lower average wind speed in hummocky tundra and the presence of a high number of owl castings and mammal scat in deep, wind-protected coulees suggested that both small and large birds as well as certain mammals seek out sheltered microhabitats during high winds. It is suggested that park operations should not interfere with the access that birds and other wildlife have to these potentially important microhabitats.

Key Words: birds, breeding distribution, abundance, habitat associations, microhabitats, wind shelter, Banks Island, Aulavik National Park, Arctic, Northwest Territories

During the summers of 1995 and 1996, a team of Parks Canada scientists and Inuvialuit inventoried the biological and archaeological resources of Aulavik National Park, a park established in 1992. This report describes the occurrence, breeding status, relative abundance, and habitat use patterns of the birds of the park.

Study Area

Aulavik National Park is a large, remote, protected area in the northern portion of Banks Island in Canada's Arctic Islands (see Figure 1). Aulavik encompasses 12 275 square kilometers of the Western Arctic Lowland Natural Region (Parks Canada 1990). Banks Island Migratory Bird Sanctuary Number 2 is within the park (see Figure 1) and is managed jointly by the Canadian Wildlife Service and Parks Canada. Aulavik National Park contains a diversity of landscapes — upland plateaus, unvegetated polar desert areas, wetlands with frost polygon features, sheer cliffs along the coast and southeast of Mercy Bay, and the lush valley of the Thomsen River (Gray and Alt 1997*). Most of Banks Island has probably been free of glaciation for millions of years or never glaciated (Zoltai et al. 1980*). All land surfaces of the park are underlain by permafrost. The average thickness of the active layer during August is approximately 50 cm, shallower on peaty soils and deeper on well-drained soils (Gray and Alt 1997*). At least 169 species of vascular plants have been recorded in Aulavik National Park (Raillard *in press*). The vegetation of the park is frequently characterized by polar semi-desert and desert community types (Bliss et al. 1984; Bliss and Svoboda 1984). Moister sites support more productive graminoid shrub tundra and wet sedge meadows. Ferguson (1991) described eight habitat types in the Muskox River valley. During our study these habitat types were verified in the Muskox, Eames, and Thomsen river valleys and were used to classify habitat for this project.

*See Documents Cited section

Methods

Field work for this bird inventory was carried out from 26 June to 2 August 1995 and 8 to 18 July 1996. In order to compare weather from these two periods to long-term averages, basic weather data were collected twice each field day (approximately 07:00 h and 19:00 h) including total precipitation, ambient temperature, wind speed, and wind direction. Wind speed was recorded with a hand-held anemometer (Dwyer Wind Meter, Dwyer Instruments Inc., Michigan City, Indiana). Cloud cover was described using standard aviation terminology. Cloud, temperature, and wind conditions were also described for each point-count.

Ten different areas of the park were inventoried for birds (see Figure 1). Every field day a list of bird species with approximate numbers was compiled. One to 12 daily checklists were compiled for each area. Number of checklists depended on how many days observers spent in each area which was determined by logistic support and other research occurring there. More time was spent in the more productive areas, and birds from these areas were better represented on the checklists than birds from less productive areas. Breeding records were recorded only for sightings of an active nest with eggs or offspring, or of an adult bird with flightless young.

From these daily checklists, bird species were grouped in three relative abundance classes: *common* (species recorded on 50 percent or more of checklists), *uncommon* (species recorded on 49 to 20 percent of checklists), or *rare* (species recorded on less than 20 percent of checklists). Because several variables influence the frequency with which a bird is recorded (e.g., conspicuousness, distance its song can be heard, reaction to humans), relative frequency of bird species, as determined by daily checklists, cannot be defined more precisely (Scotter et al. 1985).

Point-counts were carried out on three biologically productive study areas within the park: Eames River, Muskox River, and the central portion of the Thomsen River (see Figure 1). These are referred to as study areas. A standard point-count methodology for open environments (100 m radius, 5 minute observation time) was employed during this study (Ralph et al. 1995). Point-counts were carried out between 05:00 and 13:00 h, but not during inclement weather (heavy wind, fog, snow or rain). Point-counts were randomly located within a single habitat type, and perimeters of point-counts were separated from each other by at least 200 m. The centre of the point-count was marked, as well as two opposite points on the perimeter, each 100 m from the centre. The observer returned to the centre, waited approximately 1 minute to reduce disturbance effects, and then for the next 5 minutes mapped all birds seen or heard on the 100 m radius circular area as well as birds seen or heard outside the plot or flying over the plot (see Henry and Mico 1997*, for details). Movements and interactions of birds present on the plot were recorded and mapped in order to reduce the chance of recording the same bird more than once. Observers made special efforts not to record on more than one count birds that could be seen or heard over long distances (e.g., Sandhill Cranes, Common Ravens) [see Appendix for scientific names]. A total of 20 to 35 point-counts was recorded for each of eight habitat types (Ferguson 1991) on each study area. In total, 764 point-counts were recorded. During the two field seasons, none of the point-counts were revisited.

The point-count data were analyzed to examine relative abundance and habitat associations. Only 13 species were recorded on at least five point-counts and on at least two study areas. These species were judged to be recorded frequently enough to analyze their abundance and habitat associations. The relative abundance and habitat association data were not normally distributed; thus Friedman's Nonparametric Two-Way ANOVA test was used to analyze the data ($\alpha = 0.05$). If the null hypothesis that on the three study areas bird species were equally abundant (or the null hypothesis that bird species were equally abundant on all habitat types) was rejected, a multiple comparison procedure (modified Newman-Keuls test; Daniel 1990) was utilized (setting experiment-wide error at $\alpha = 0.10$; Daniel 1990). This latter test was used to determine which species exhibited significantly different abundance values across the three study areas and across the habitat types.

To assess the extent that hummocky tundra can provide shelter for small birds during windstorms, wind speed was measured with a hand-held anemometer on days that exhibited an average wind speed of 15 k/h at 1.5 m above ground. Wind speed measurements at 35 different locations were taken at several different heights: 150 cm above ground, 100 cm, 50 cm, 20 cm, 10 cm, 0 cm as well as in the bottom of microdepressions between hummocks. Average wind speed measurements were normally distributed and were tested for significant differences using a single factor ANOVA analysis (Sokal and Rohlf 1969).

Pellet-count transects tested whether coulees were selectively used by large birds and large mammals as compared to areas of surrounding tundra. Randomly selected paired 100 m transects were set up, one transect in the bottom of a sheltered coulee and the other on nearby flat, open tundra. On each transect, all scats and owl castings within 1 m of the transect centreline were recorded. Five pairs of transects were sampled for each of three different sheltered coulees. A t-test ($n = 15$) was used to analyze for significant differences in scats and castings on the two types of transects (Sokal and Rohlf 1969).

Results and Discussion

Weather Patterns

Research from the nearest permanent weather stations, at Sachs Harbour on Banks Island and Mould Bay on Prince Patrick Island, provided by Meteorological Services of Canada, Environment Canada (1996*) were used to calculate long-term weather averages (Table 1). Both weather stations are located near the coast whereas the study areas were 15 to 40 km inland from M'Clure Strait. The difference in weather of coastal regions compared to more inland parts of Banks Island has not been studied in detail. Coastal regions may be cooler, foggier, and wetter than more inland locations (Zoltai et al. 1980*).

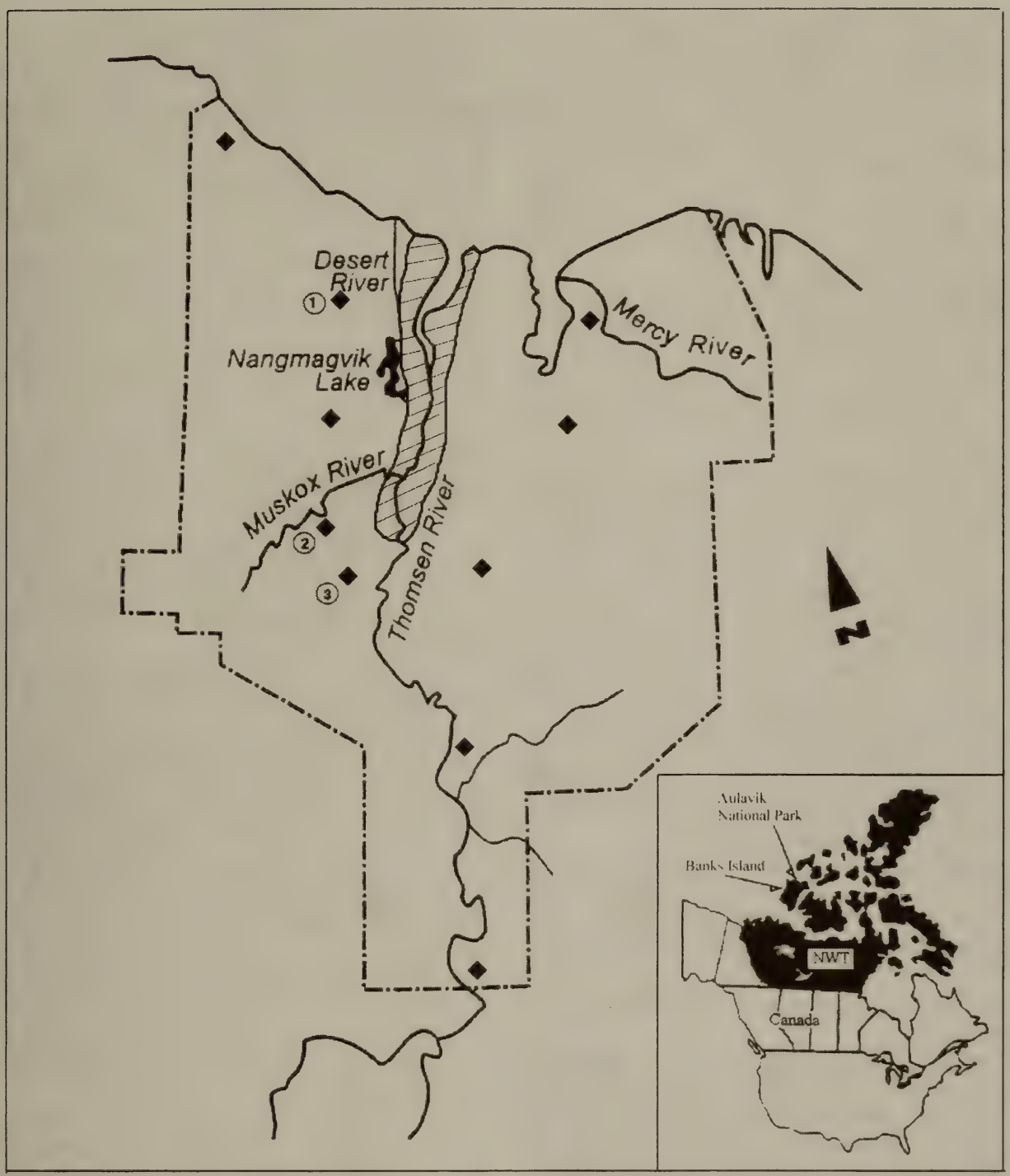

FIGURE 1. The location of Banks Island and Aulavik National Park. The centre of the park is located at approximately 73°42′N, 119°20′W. The hatched area on the map is Banks Island Bird Sanctuary Number 2 managed jointly by the Canadian Wildlife Service and Parks Canada. The ◆ indicates the ten areas of Aulavik National Park where daily checklists of bird species were compiled. The numbers indicate the three study areas of the park where point-counts were carried out. These study areas are as follows: (1) Eames River, (2) Muskox River and (3) central portion of the Thomsen River.

The 1995 field season was generally warmer, wetter, and calmer and the 1996 field season was warmer and calmer than the long-term averages (Table 1). Thus most of the field work for this project was carried out under average to good weather conditions. Two periods (22 July to 2 August 1995 and 18 to 26 July 1996) were characterized by precipitation and/or strong winds. No point counts were carried out during these periods of inclement weather.

Classification of Habitat Types

All habitats sampled during this study were classified according to Ferguson (1991) with slight modifications relevant to avian species (for details, see Henry and Mico 1997). As listed below, the terrestrial habitat types progress from wet, low sites with higher aboveground primary productivity to xeric, less productive sites at higher elevations. The habitat types used in this study are:

Water Bodies (WB). This habitat type includes open water of lakes, rivers, streams, and tundra ponds.

Wet Sedge Meadows (WSM). This type occurs on level, hydric lowlands. It is usually covered by shallow (<10 cm) water and a nearly continuous cover of sedges, especially *Carex aquatilis* var. *stans*, and other hydrophytic species.

Graminoid Tundra (GRT) occupies mesic to hygric sites in lowlands and on gentle slopes, with continuous cover of graminoid species, and sometimes dwarf shrubs (usually *Salix* species). Plant growth is most luxuriant on gentle slopes downslope from snowbeds.

Graminoid/Dwarf Shrub Tundra (GST). This type is intermediate between graminoid tundra and dwarf shrub tundra in terms of moisture and vegetation. Vegetation cover, characteristically between 75 to 100 percent, is a mosaic with graminoids and mosses dominate in moist depressions and herbs and dwarf shrubs dominate on the drier hummocks.

Dwarf Shrub Tundra (DST) occurs on moist, well-drained, middle and upper slopes as well as solifluction lobes and terraces. Vegetation cover, characteristically 50 to 75 percent, is dominated by dwarf shrubs, especially *Salix arctica* and *Cassiope tetragona*. Small, non-sorted polygons as well as cryoturbated surfaces are often present.

Hummocky Tundra (HT). This type is non-sorted earth hummocks covering small to extensive areas. Narrow furrows and cracks separating the hummocks support mosses, lichens, herbs, and sometimes dwarf shrubs. The tops and sides of hummocks are dry and often free of vegetation.

Dwarf Shrub/Lichen Barrens (DLB). This variable type occurs at all elevations on windblown sites. Typically sites are rapidly drained, consisting of silty to stoney soils. Vegetation, characteristically 25 to 50 percent cover, is dominated by mat and cushion plants.

Sparsely Vegetated Ground (SVG) is characterized by less than 10 percent vascular plant cover. This type occurs on cutbanks, mudflats, sand and gravel bars, uplands, windblown sites, sand dunes, frost-shattered bedrock, debris-mantled slopes, and bare sandstone.

Lists of Bird Species for Aulavik National Park and Banks Island

On the basis of literature review and fieldwork, Zoltai et al. (1980*) listed 40 bird species in Aulavik National Park. During eight weeks of fieldwork for this project, we added only four new bird species to the park's list: Tundra Swan, Red-necked Phalarope, Western Sandpiper, and Purple Sandpiper. Henry and Mico (1997*) provide details of these sightings.

Zoltai et al. (1980*) reported Gyrfalcons and Thayer's Gulls in the park area. Wilkinson et al. (1977*) reported Lesser Yellowlegs in the park area, but Zoltai et al. (1980*) considered this species as hypothetical. These three bird species were not observed during this study. Thus in total, 44 bird species have been recorded in Aulavik National Park, 41 of which were observed during this study (Table 2).

Zoltai et al. (1980*) summarized all prior sightings of bird species for the park as well as for Banks Island. This list was updated (see Appendix), and it now incorporates all documented and reported sightings and breeding records up through 2001. Several interesting patterns are evident. Amundsen Gulf, which separates Banks Island from the mainland, is confirmed to be an effective geographic barrier to migrating birds. For example, 143 bird species have been recorded in Ivvavik National Park in the northern Yukon Territory (Holcroft Weerstra 1997*) and 127 species in Vuntut National Park (Gray and Alt 2000*; Henry et al. 2002) as compared to 74 bird species for Banks Island and 44 species in Aulavik National Park (see Appendix).

The fact that only 44 out of 74 bird species observed on Banks Island have been observed in the park may reflect the limited research effort in the park. It might also reflect the reduced biological productivity and wider distribution of polar desert habitat in the park as compared to other parts of Banks Island (Gray and Alt 1997*; Raillard *in press*).

There are documented sightings for 23 bird species (plus seven species recorded as hypothetical) in other parts of Banks Island that have not yet been observed in Aulavik National Park (see Appendix). This difference includes a variety of species, for example, waterfowl (Ross' Goose, Northern Pintail, Common Eider, and Red-breasted Merganser); a raptor (Short-eared Owl); a shorebird (Whimbrel) as well as a passerine species (Barn Swallow).

The Appendix includes single sight records for the Western Sandpiper in Aulavik National Park as well as 13 additional bird species on Banks Island. Because a specimen was collected, a photograph was obtained, or a detailed description was provided,

TABLE 1. Weather parameters for July 1995 and July 1996 compared to long-term averages for July from the nearest permanent weather stations.

	Aulavik Study Area		Sachs Harbour	Mould Bay
	1995 26 June–02 August	1996 19–28 July	1955–1990 July Long-term Mean	1948–1990 July Long-term Mean
Mean Daily Max. Temp (°C)	12.0	12.8	10.0	6.5
Mean Daily Min. Temp (°C)	2.7	4.0	3.0	1.1
Average Wind Speed	13.0	10.0	n/a	18
Total Precipitation (mm)	125.0	20.0	15.7	14.2

TABLE 2. Relative abundance, based on daily checklists, and breeding status of 41 avian species observed in Aulavik National Park during the summers of 1995 and 1996. Common species were recorded on 50 percent or more of the daily checklists, uncommon on 20 to 49 percent, and rare on less than 20 percent of the checklists. Breeding records listed as new were established as a result of field observations made during this study.

Species	Relative Abundance	Breeding Record
Red-throated Loon*	Rare	
Pacific Loon*	Uncommon	X new
Yellow-billed Loon*	Rare	X new
Snow Goose*	Rare	
Canada Goose	Rare	X new
Brant*	Uncommon	X new
Tundra Swan	Rare	
King Eider**	Uncommon	X new
Long-tailed Duck*	*Rare	X new
Rough-legged Hawk	Uncommon	X
Peregrine Falcon**	Rare	X
Willow Ptarmigan	Rare	X new
Rock Ptarmigan**	Rare	X
Sandhill Crane	Common	X new
Black-bellied Plover**	Common	X new
American Golden-Plover**	Uncommon	X new
Semipalmated Plover	Rare	
Ruddy Turnstone**	Rare	X new
Purple Sandpiper*	Rare	X new
Sanderling*	Rare	X
Semipalmated Sandpiper	Uncommon	X
Western Sandpiper	Rare	
Least Sandpiper	Rare	
White-rumped Sandpiper**	Rare	X new
Baird's Sandpiper**	Uncommon	X
Pectoral Sandpiper*	Uncommon	X new
Buff-breasted Sandpiper	Rare	X new
Red-necked Phalarope	Rare	
Red Phalarope**	Rare	X new
Pomarine Jaeger*	Rare	
Parasitic Jaeger*	Rare	
Long-tailed Jaeger*	Common	X new
Glaucous Gull**	Common	X
Sabine's Gull*	Rare	X
Arctic Tern**	Uncommon	X new
Snowy Owl*	Uncommon	X
Common Raven*	Uncommon	X new
Horned Lark*	Common	X
American Pipit*	Rare	X
Lapland Longspur **	Common	X new
Snow Bunting**	Uncommon	X new

*Species is known to occur in both Truelove Lowland, Devon Island (Pattie 1990) and Aulavik National Park (this study).
**Species is known to occur and breed regularly in both Truelove Lowland, Devon Island (Pattie 1990) and Aulavik National Park (this study).

these 14 species records are considered to be accurate, and the Appendix lists these species as accidental occurrences on Banks Island. These species include: Northern Fulmar, Spectacled Eider, Western Sandpiper, Black Guillemot, Tree Swallow, Barn Swallow, Black-billed Magpie, Northern Waterthrush, American Redstart, Common Redpoll, American Tree Sparrow, Harris's Sparrow, White-crowned Sparrow, and Fox Sparrow. The Appendix lists another seven bird species as hypothetical occurrences on Banks Island, and these species need confirmation. These species include: Greater White-fronted Goose, American Wigeon, Lesser Yellowlegs, Dunlin, Black-legged Kittiwake, Thick-billed Murre, and Dovekie.

Large rocky and sandy barren areas, often described as polar deserts, are widely distributed on several Canadian High Arctic Islands (Bliss et al. 1984) and occur often in Aulavik National Park. These areas are at least a square kilometer in size, sparsely vegetated and include windblown ridges, high rocky uplands, sand dunes, talus slopes below

cliffs, as well as large mud flats and gravel bars in or adjacent to rivers. In Aulavik they cover 11.7 percent of the total area (Raillard *in press*). Birds are infrequently observed in these polar desert areas. For example, during mid-July 1996, six hours of surveying such areas west of Nangmagvik Lake (see Figure 1) yielded only four birds — one Long-tailed Jaeger, one Horned Lark, and two Lapland Longspur. Sightings of approximately one bird per hour were typical for the driest of these polar desert areas.

Bliss and Svoboda (1984) described the wide distribution of polar semi-desert habitat among Canadian Arctic Islands north of 70° latitude. In Aulavik National Park 24.5 percent of the park area is classified as polar semi-desert (Raillard *in press*). The ground surface of these areas is stony or covered with sand and clay, and plant cover is between 10 and 50 percent (see Raillard *in press*, for details). Together, polar desert and polar semi-desert areas constitute 36.2 percent of Aulavik National Park. These areas are characterized by few bird species and low avian densities.

Checklists of Birds Observed on Each Field Day

Observers compiled separate checklists of birds each day in the field. Six out of 41 species (15 percent) were *commonly* observed; 12 species (29 percent) were *uncommonly* observed, and 23 species (56 percent) were *rarely* observed in these areas of the park (Table 2). Patterns observed during the two summers were relatively consistent. Thirty-eight bird species were observed in the 1995 field season, and 35 species in the 1996 field season. The Red-throated Loon, Tundra Swan, Sabine's Gull, Sanderling, Western Sandpiper, and American Pipit were recorded only in 1995. The Semipalmated Plover, Red-necked Phalarope, and Least Sandpiper were recorded only in 1996.

Checklists were compiled for ten areas in the park; thus, many other areas still need to be studied. However, as eight weeks of fieldwork found only four new bird species, these results suggest that the avifauna of Aulavik National Park is fairly well documented.

The 44 species recorded in the park seem to be typical bird species observed in the Middle Arctic region (Pielou 1994). During 16 years of censusing breeding bird populations on Truelove Lowland, Devon Island, Nunavut (75°41′N, 84°35′W), Pattie (1990) recorded 43 species of birds, 18 as regular breeders. The avian communities from these two locations are similar. Seventy percent (31 out of 44 species) occurs in both Aulavik National Park and Truelove Lowland (these species are marked as * or ** in Table 2, plus Thayer's Gull, see Appendix). Of the 18 regular breeders in Truelove Lowland, 14 species (78 percent) breed in Aulavik National Park. These similarities suggest that the same avian species occur over much of the Middle Arctic and breed there. Other localities in the Middle Arctic should be examined for this assemblage of species.

Breeding Bird Records for Aulavik National Park

As a result of their literature review and fieldwork, Zoltai et al. (1980*) listed 12 breeding bird species in the park area (see Appendix). Using more exact criteria for breeding records (see Methods), our study documented breeding by 21 additional species in Aulavik National Park (Table 2). For three species, this study also extends the known detailed breeding range as presented by Godfrey (1986) and updated by Sibley (2000). These three species are: Semipalmated Sandpiper, Purple Sandpiper, and Buff-breasted Sandpiper. In summary, 33 of the 44 bird species (75 percent) known to occur in Aulavik National Park are now known to breed there (Table 2, plus Thayer's Gull in the Appendix).

Nests of Peregrine Falcons, arctic race, containing flightless offspring were observed on cliffs adjacent to a river and a stream within the park. Gyrfalcon Bluff is the only location on Banks Island where Gyrfalcons have been documented to nest and raise young. However, Gyrfalcons have not been observed nesting there since 1979. A review of sightings of Gyrfalcons (Henry and Mico 1997*) supports the view that Gyrfalcons are rare in Aulavik National Park and may not nest there at present. Cliff nesting sites for Peregrines, Gyrfalcons and Rough-legged Hawks occur infrequently over much of the interior of Aulavik National Park and may be a limiting factor for these populations. For example, on three occasions Rough-legged Hawks nested and laid eggs on flat-topped boulders that were 2 m or less above ground level. These nests seemed easily accessible by Arctic Foxes and other predators. If future field research supports that cliff nesting sites for raptors are rare in the park, these sites may warrant special management action to protect them from human disturbance.

Relative Abundance of Common Bird Species

Daily checklists give a coarse indication of relative abundance of bird species (Table 2). The point-count method (Ralph et al. 1993, 1995) is a more quantitative technique, and it was used to estimate the relative abundance and examine the habitat association patterns for common bird species. Point-counts were used on three study areas (see Figure 1): Eames River area (centered at 74°06.2148N, 120°45.07′78W), Muskox River area (centered at 73°45.6778N, 120°34.849W), and the central portion of the Thomsen River area (centered at 73°13.8498N, 119°32.4228W). There are significant differences among the relative abundances of 13 bird species (Friedman's ANOVA, $P < 0.05$).

The Lapland Longspur was the most abundant bird species on these three study areas. Its relative abundance was at least three to five times higher than the next most numerous bird species, Black-bellied Plover.

Black-bellied Plover was consistently ranked between second and fourth in all estimates and averaged the second most common bird species on the study areas. The relative abundances of Horned Lark and Baird's Sandpiper are significantly lower (Newman-Keuls test, $P < 0.10$). Their relative abundances are nearly equal, and they tied as the third most common species on the study areas. Relative abundance of Horned Lark is more variable than that of Baird's Sandpiper.

Long-tailed Jaeger was fourth in abundance but shows variation, being more abundant on the Muskox River and Thomsen River study areas than on the Eames River study area. The relative abundance of Pectoral Sandpiper and Sandhill Crane is significantly lower than that of Long-tailed Jaeger, and these two species are tied for fifth in abundance on the study areas. Red Phalarope and Glaucous Gull are tied for sixth in abundance, and they are only slightly less abundant than Pectoral Sandpiper and Sandhill Crane.

American Golden-Plover, King Eider, and Pacific Loon are tied for seventh in abundance. The American Golden-Plover and Pacific Loon show little variation in abundance among study areas. The King Eiders were mostly females raising young on the inland areas of Banks Island while the males during summer tend to congregate along the coast.

The Brant is the least common of these 13 avian species. However, it was relatively common on the Muskox River study area, where a flock of over a hundred birds was observed repeatedly on a small lake.

The composition and relative abundance of the avian community vary as habitats and ecological conditions in different parts of Aulavik National Park change. Some of the relatively common bird species, as determined by point-counts, were found to be *uncommon* (Baird's Sandpiper, Pectoral Sandpiper, American Golden-Plover, King Eider, Pacific Loon and Brant) or even *rare* (Red Phalarope) as determined by daily checklists (Table 2). The point-counts were carried out in biologically productive areas of the park whereas the daily checklists were from areas varying from polar deserts to productive river valleys.

Habitat Association Patterns

For each study area, overall avian density (mean number of individual birds of all species per point count) was calculated for each habitat type. Certain habitat types supported significantly higher density of birds than others (Friedman's ANOVA, $P < 0.05$). The data showed a relationship between available surface moisture and avian density: wet habitats had the highest abundance of birds. Water bodies (WB), graminoid-dwarf shrub tundra (GST), and graminoid tundra (GRT) had the highest density of birds. Wet sedge meadow (WSM), however, had only intermediate avian abundance. Hummocky tundra (HT) is mesic and has an intermediate avian density. Finally, sparsely vegetated ground (SVG), dwarf shrub-lichen barrens (DLB), and dwarf shrub tundra (DST) are dry habitats with low density of birds.

Vegetation cover (which is also related to available surface moisture) also appeared to be a good predictor of density of birds in certain habitats: terrestrial sites with 75 percent or less vegetation cover had the lowest avian densities. In descending order of vegetation cover and avian abundance, these sparsely vegetated habitat types are ranked DST > DLB > SVG.

As discussed above, bird densities respond to surface moisture and habitat productivity: with some exceptions, habitats with high surface moisture exhibit higher bird densities. Point-counts were also utilized to determine habitat association patterns based on Ferguson's (1991) habitat types for each of the 13 common bird species. Nine out of 13 species showed no significant preference for any of these

TABLE 3. List of mean ± standard deviation of birds from 764 point-counts with 100 m radii. Densities given for the 13 most common bird species in Aulavik National Park according to the eight habitat types (n = number of individual birds observed). Bird species names are abbreviated by using first three letters of separate words in the AOU name for the bird (e.g., BLA PLO means Black-bellied Plover).

Species	WB (n=68)	WSM (n=91)	GRT (n=100)	GST (n=101)	DST (n=85)	HT (n=104)	DLB (n=96)	SVG (n=120)	P =
PAC LOO	.32 ± .42	.06 ± .09	.03 ± .06	.03 ± .03	0.00.	02 ± .03	.0.00	.03 ± .06	0.349
BRA	.51 ± 9.6	.05 ± .10	.11 ± .13	.02 ± .04	.03 ± .07	0.00	0.00	.0.00	0.371
KIN EID	.98 ± 1.1	.16 ± .20	.19 ± .39	.14 ± .11	0.00	0.00	.28 ± .34	0.00	0.234
SAN CRA	.07 ± .10	.11 ± .18	.02 ± .05	.20 ± .33	.05 ± .10	.07 ± .11	.16 ± .29	.09 ± .06	0.826
BLA PLO	.28 ± .35	.31 ± .14	.28 ± .24	.47 ± .49	.29 ± .19	.13 ± .09	.12 ± .08	.06 ± .07	0.085
AME GOL	.01 ± .02	.02 ± .03	.35 ± .07	.32 ± .42	0.00	.04 ± .03	.05 ± .07	01 ± .02	0.738
RED PHA	.07 ± .11	.26 ± .27	.03 ± .07	.01 ± .03	0.00	0.00	0.00	0.00	0.397
BAI SAN	.05 ± .03	.16 ± .10	.21 ± .22	.06 ± .07	.17 ± .22	.18 ± .16	.12 ± .14	.08 ± .05	0.467
PEC SAN	.12 ± .14	.05 ± 07	.08 ± .16	.01 ± .03	0.00	0.00	0.00	0.00	0.787
LON JAE	.20 ± .16	.14 ± 18	.18 ± .13	.30 ± .24	.27 ± .21	.16 ± .19	.43 ± .42	.14 ± .11	0.304
GLA GUL	.30 ± .37	.10 ± .10	.24 ± .19	.24 ± .23	.15 ± .27	.07 ± .11	.09 ± .04	.02 ± .02	0.064
HOR LAR	0.00	.01 ± .01	.05 ± .08	.17 ± .06	.12 ± .08	.17 ± .12	.17 ± .09	.10 ± .13	0.062
LAP LON	.74 ± .89	1.3 ± .87	1.5 ± 1.1	1.8 ± .85	1.2 ± .25	2.2 ± .65	.89 ± .52	.65 ± .32	0.015

habitat types (Table 3, Newman-Keuls test, $P > 0.10$). At this level of habitat classification, these species appear to be habitat generalists. Lapland Longspur, Horned Lark, Glaucous Gull, and Black-bellied Plover were significantly associated with certain habitat types (Table 3, Newman-Keuls test, $P < 0.10$) as follows:

Lapland Longspurs were most abundant on HT and GST but seemed least abundant on or immediately next to WB, SVG, and DLB. Horned Larks were similar to but not identical with Lapland Longspurs. Horned Larks were most abundant on HT, GST, and DLB. However, this species seemed least abundant on or next to WB or on WSM and GRT — all habitat types with high surface moisture.

Glaucous Gulls are a wide-ranging species, especially while foraging. However, they were most commonly observed on or next to WB where they nested on small islands in medium to large tundra ponds. They were also frequently observed in mesic sites such as GRT and GST, but they were rarely observed on SVG.

Black-bellied Plovers were rarely observed on SVG. This species appeared to be adapted to a wide range of moisture conditions, being most commonly observed quite near WB or on WSM, GRT, GST, and DST.

During his sixteen-year study of the birds of Truelove Lowland, Pattie (1990) documented a negative correlation between the decreasing population of Black-bellied Plovers and increasing American Golden-Plovers. On several occasions he observed American Golden-Plovers pursuing Black-bellied Plovers and suggested that there may be competition between these species. On the Aulavik study areas, Black-bellied Plovers were four times more abundant than American Golden-Plovers, and no agonistic interactions between these species were observed. Although American Golden-Plovers showed no significant habitat associations, they were most frequently observed on GRT, whereas Black-bellied Plovers were observed on a wide range of moist habitat types. It may be that competitive interactions between these species do not occur until the population of American Golden-Plovers reaches a certain threshold density.

The number of bird species observed in each habitat type was examined. Seven of the habitats showed no significant differences in the number of bird species observed (Newman-Keuls test, $P > 0.10$). SVG supported fewer bird species (Newman-Keuls test, $P < 0.10$). SVG on river banks and gravel bars of the central portion of the Thomsen River supported more bird species than similar habitat on the Eames River or Muskox River. The Thomsen River is one of the largest rivers in the park and may have less permafrost and more invertebrates associated with its gravel bars and river banks than other rivers and streams in the park.

Shelter During Storms

Finding shelter from the wind can be critically important to many plants and animals on the tundra. During a typical summer in the Middle and High Arctic, strong windstorms accompanied by near-freezing temperatures and rain or snow can last a week or longer before abating (Pielou 1994). Reducing heat loss and minimizing energy expenditure during storms may be critical to survival of small birds and their offspring (Rodrigues 1994). Wiersma and Piersma (1994) and Rodrigues (1994) discussed the importance of energy-conserving behaviours by birds, such as the selection of nest sites. Hummocky tundra provides shelter for the nests of many arctic-breeding passerines (Ehrlich et al. 1988). During this study several pairs of Lapland Longspurs and Snow Buntings were observed to nest in hummocky tundra or other small microdepressions. Terrain such as hummocky tundra may also be critical in providing shelter for all adult passerines during wind and rainstorms. Aboriginal people and naturalists have often observed that small birds on the tundra seem to take shelter during periods of high winds (e.g., Rand 1948; Porsild 1951). When a person walks through hummocky terrain during such times, Lapland Longspurs, Horned Larks and other small birds often explode into flight out of small depressions in the tundra.

To test the potential shelter provided by these microhabitats, wind profiles were measured at 35 locations when the average wind speed was approximately 15 k/h (see Methods and Figure 2). Average wind speed at the bottom of microdepressions was 1/20th of what it is at 150 cm above ground and nearly 1/10th of wind speed at ground level (single factor ANOVA, $P < 0.0001$). Protection from wind is not simply a function of depth but also a function of verticalness of walls and overhang of uppermost edges of microdepression. Nine microdepressions with these favourable features were measured, and wind speed was reduced to approximately 1/1000th of what it was 150 cm above ground. Consequently, by carefully choosing the microdepression where they nest or those they occupy during a windstorm, small passerines might reduce heat loss considerably.

Larger birds (e.g., cranes, geese, and ptarmigans) and mammals that do not den underground (e.g., muskoxen and caribou) also might seek shelter during periods of high wind and precipitation. In Aulavik National Park, deep and narrow coulees occasionally form along small creeks near their confluence with larger rivers. During a twelve-day period of wind, rain, and snow in early August 1995, JDH observed a pair of Sandhill Cranes, a Common Raven, and a ptarmigan standing in the bottom of one of these coulees for more than five hours. These birds were feeding only infrequently. Most of the time they simply stood quietly, within 10 m of each other, apparently seeking shelter from the storm.

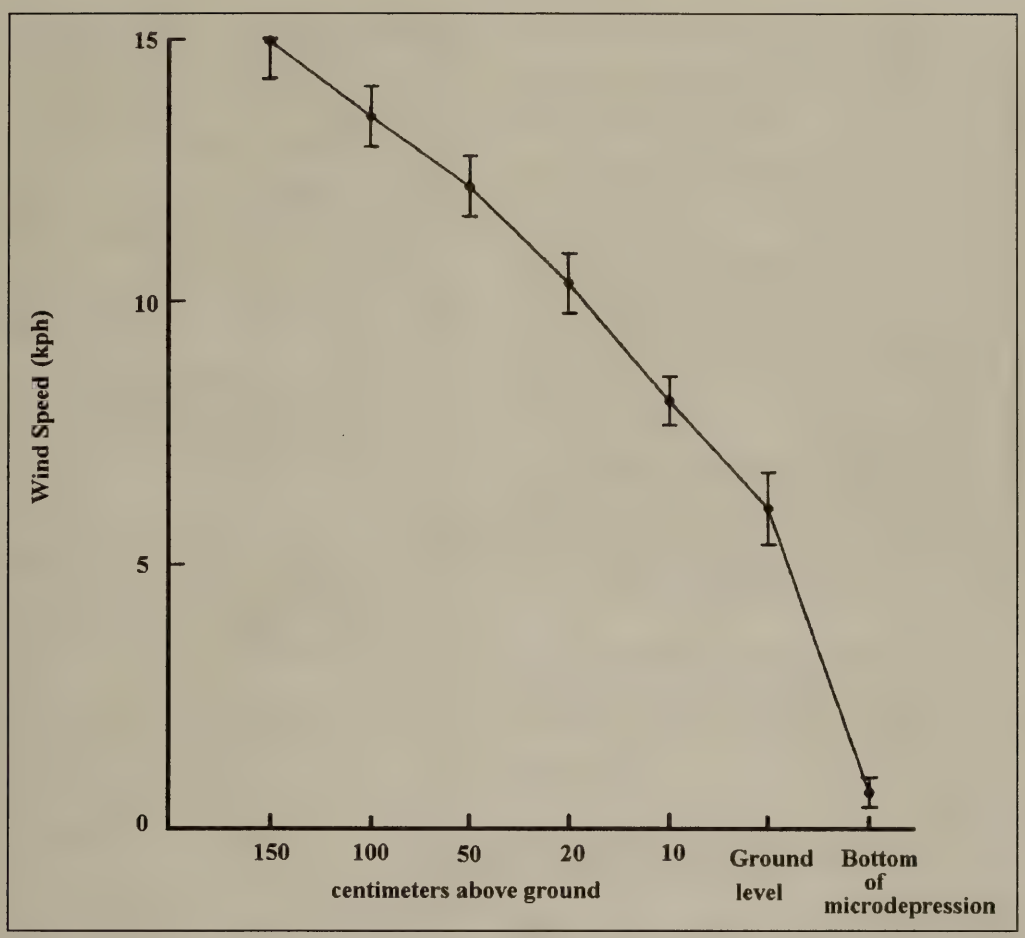

FIGURE 2. Wind speed (mean and standard error) at various distances above the ground and in the bottom of microdepressions of hummocky tundra.

Paired pellet-count transects indicate that large birds and certain mammals defecate more in these coulees than in open tundra areas immediately adjacent to them. This distribution of scat suggests that these animals spend selectively more time there. In 15 different locations, droppings of large birds and mammals were from five to ten times more numerous in sheltered coulees than in adjacent tundra areas ($x_{coulees} = 22.1$ scats; $x_{tundra} = 1.8$ scats; $t = 6.346$, $P < 0.001$). Wind speed measurements suggested that narrow, steep-walled coulees oriented perpendicular to prevailing winds offer considerable shelter during windstorms. Such coulees were extremely rare in the ten areas of the park examined. It is recommended that park staff and visitors avoid using these coulees, and that no park facilities are developed near these areas so as not to interfere with free access by large birds and mammals to these potentially important microhabitats.

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Appendix: A list of all bird species observed and all avian breeding records documented for Banks Island, N.W.T., and Aulavik National Park.

The sources of information summarized in this appendix are as follows: P= Porsild (1951); MHM = Manning et al. (1956); Mah = Maher (1964*); K = Kevan (1971*); W = Wilkinson et al. (1977*); ZKS = Zoltai et at. (1980*); HM = Henry and Mico (1997*); CH = Cotter et al. (1999*); O = others.

In this appendix, status and relative abundance are defined as follows: Species that are common (C) will be recorded on a majority of field days in suitable habitats. Uncommon species (U) are likely to be recorded on 20 to 50 percent of field days in suitable habitats. A rare species (R) is likely to be recorded on less than 20 percent of the field days in suitable habitats. Accidental (A) refers to species that are unlikely to occur more often than several times in a decade. Hypothetical (H) refers to records which are unsubstantiated by specimens, photographs or detailed descriptions. These species need confirmation. Breeder (B) refers to species for which there are valid breeding records. Summer residents (SR) are species which occur in summer but for which breeding has not been recorded. Permanent residents (PR) occur throughout the year. No sightings for certain bird species within Aulavik National Park and (up to June 2001) are indicated by no record (NR).

Under "sources of information" the following abbreviations are used:

T = recorded in the Aulavik National Park area (see Zoltai et al. 1980*);
T* = breeding record in the Aulavik National Park area (see Zoltai et al. 1980*);
X = recorded from other parts of Banks Island;
X* = breeding record for other parts of Banks Island;
A = recorded from Aulavik National Park during this research project;
A* = breeding record from Aulavik National Park recorded during this research project.

Appendix. Species/breeding record list from Banks Island and Aulavik National Park.

Species	Banks Island	ANP	Habitats where often observed	Source of Information P	MHM	Mah	K	W	ZKS	CH	HM	O	Remarks
Red-throated Loon *Gavia stellata*	C-B	R-SR	Tundra ponds		T	X	T		T	X*	A		Cotter et al. (1999) observed 2 nests, each with 2 eggs on Banks Island
Pacific Loon *Gavia pacifica*	C-B	U-B	Tundra lakes		T	X		T	T	X*	A*		Lower Thomsen River and Castel Bay are critical molting areas.
Yellow-bellied Loon *Gavia adamsii*	U-B	R-B	Lakes in high arctic		T	X		T		X*	A*		Pair observed in pond (HM); pair with downy chick in Nangmagvik Lake (Kudlak, 24 July 1996)
Northern Fulmar *Fulmarus glacialis*	A		NR									X	Rand (1948) reports specimen at Cape Kellett, 27 July 1916.
Greater White-fronted Goose *Anser albifrons*	R-B	NR			X								Pair and active nest observed on Banks Island (Manning et al. 1956)
Snow Goose *Chen caerulescens*	C-B	C-SR	Lower Thomsen R. Castel Bay	X	T	X	T		T	X*	A		Lower Thomsen River and Castel Bay are critical molting areas.
Ross's Goose *Chen rossii*	R-B	NR			X								200 birds may nest in southwestern Banks Island (Barry 1961).
Canada Goose *Branta canadensis*	U-B	R-B	Lower Thomsen R.		X			X	T	X*	A*	X	Beak (1975) reports moulting flock on lower Thomsen River. Few birds observed in Mercy Bay (HM); nest on island in tundra pond next to the Thomsen River; eggs hatched 10 July 1996 (Catto, personal observation)
Brant *Branta bernicla nigricans*	C-B	U-B	Lower Thomsen R. Castel Bay		T	X	T	T	T	X*	A*		Castel Bay is a critical moulting area. Occupied nest observed (Catto, 9 July 1996)

continued

Appendix (*continued*). Species/breeding record list from Banks Island and Aulavik National Park.

Species	Banks Island	ANP	Habitats where often observed	Source of Information P	MHM	Mah	K	W	ZKS	CH	HM	O	Remarks
Tundra Swan *Cygnus columbianus*	U-B	R-SR	Tundra ponds		X					X	A		200 nest in southwest Banks Island (Barry 1961); adult and three flying young on Thomsen River (Harry, 25 July, 1995)
American Wigeon *Anas americana*	H				X								Hypothetical on Banks Island (Manning et al. 1956)
Northern Pintail *Anas acuta*	R-B	NR		X						X		X*	Accidental on Banks Island (Manning et al. 1956). Holyoak (1983) found a nest with 5 eggs near Sachs Harbour.
King Eider *Somateria spectabilis*	C-B	U-B	Marine areas, tundra lakes	X	T	X*	T	T	T	X*	A*		Two nests on Eames River. Ducklings and adult females observed on lake (Henry, 14 July 1996)
Common Eider *Somateria mollissima*	C-B	NR	Marine areas		X					X*			Occurs on south and west coasts of Banks Island; nests on sandbars along the coast or on islands with Brants (Cotter et al., 1999)
Spectacled Eider *Somateria fischeri*	H			X									Sight record, Sachs River (Manning et al. 1956) Needs confirmation for Banks Island
Long-tailed Duck *Clangula hyemalis*	C-B	R-B	Rivers, lakes, coasts	X*	T	X	T	T	T	X*	A*		Breeds near large lakes in study area, ducklings observed (Harry, 18 July 1995)
Red-breasted Merganser *Mergus serrator*	R-B	NR								X		X	Sight records, Nelson Head (Latour and Allison 1976)
Rough-legged Hawk *Buteo lagopus*	C-B	U-B	Cliff-nests. See text.	X	T*	X		T*	T*	X*	A*		2 adults defending nest on cliff from 2 jaegers (Henry, 15 July 1995); nest with 3 downy flightless young observed (Kudlak, 22 July 1996)
Gyrfalcon *Falco rusticolus*	U-B	R-B	Gyrfalcon Bluff	T*	T*		T		T	T			Gyrfalcon Bluff is the only confirmed nesting area on island (HM)
Peregrine Falcon *Falco peregrinus*	R-B	R-B	Cliff-nests. See text.	T*	T	X		T*		X	A*		Falcon mobbed by 10 jaegers (Henry, 17 July 1995). Nest with 2 chicks and 2 eggs observed on Thomsen River (Catto, Rowland & Harry, 12 July 1996)
Willow Ptarmigan *Lagopus lagopus*	C-B	R-B	Willow thickets in tundra		T	X*				X	A*		Nest with 10 small eggs observed (Kudlak, 2 July 1995)
Rock Ptamigan *Lagopus mutus*	C-B	R-B	Dryas tundra	X*	T	X*	T	T	T*	X	A*		Breeds on Melville Island (Maltby 1978); three adults with 14 chicks observed (Kudlak, 22 July 1996)
Sandhill Crane *Grus canadensis*	C-B	C-B	Moist tundra		T	X	T	T	T	X	A*		Breeds at Mercy Bay (Godfrey 1986); two adults with flightless young observed on Muskox River (Henry, 20 July 1995); Reed (1988) outlines crane breeding season on Banks Island
Black-bellied Plover *Pluvialis squatarola*	C-B	C-B	Dryas tundra, mesic tundra	X	T	X*	T	T	T	X*	A*		Common breeder on tundra near waterbodies

continued

Appendix (*continued*). Species/breeding record list from Banks Island and Aulavik National Park.

Species	Banks Island	ANP	Habitats where often observed.	Source of Information P	MHM	Mah	K	W	ZKS	CH	HM	O	Remarks
American Golden-Plover *Pluvialis dominica*	C-B	U-B	Mesic tundra		T*	X*	X	T	T	X	A*		Adults with flightless goslings observed during July 1995 & 1996 (Henry, Kudlak and Mico)
Semipalmated Plover *Charadrius semipalmatus*	C-B	R-SR	Dryas tundra		T					X	A		One individual observed south of Mercy River (Kudlak, late July 1995)
Lesser Yellowlegs *Tringa flavipes*	H	H					T						Included in species list from Wilkinson et al. (1977); needs confirmation for Banks Island and ANP
Whimbrel *Numenius phaeopus*	A	NR	Moist tundra		X					X			Present on southwestern part of Banks Island where Cotter et al. (1999) observed this species in 12 different locales
Ruddy Turnstone *Arenaria interpres*	C-B	R-B	Dryas tundra, sedge tundra		T	X*		T	T	X	A*		Adults with flightless young on Thomsen River (Henry, 25 July 1995)
Purple Sandpiper *Calidris maritima*	U-SR	U-B	Mesic tundra, rivers		X						A*		Sightings by Lynch in 1994 and by Henry in 1995; known to breed on Melville Island (Dunn and Blom 1987); adult closely attending chick (Catto, Mico & Henry, 6 July 1996)
Dunlin *Calidris alpina*	H			X									Hypothetical for Banks Island (Manning et al. 1956).
Sanderling *Calidris alba*	C-B	R-B	Dryas tundra, polar desert	X	T	X*		T	T*	X*	A		Juvenile flying on Thomsen River (Henry & Harry, 26 July 1995)
Semipalmated Sandpiper *Calidris pusilla*	U-B	U-B	Mesic tundra, Dryas tundra		T	X*	T*	T	T	X	A*		Four eggs observed in nest (Henry, 27 June 1995); fledglings observed (Catto, 9 July 1996)
Western Sandpiper *Calidris mauri*	R-SR	R-SR	Feeds on gravel bars near river								A		Henry described three juveniles near Thomsen River on 2 August 1995.
Least Sandpiper *Calidris minutilla*	A	A									X		Jeff Sowiak observed one bird several times on the Thomsen River during June 1996.
White-rumped Sandpiper *Calidris fuscicollis*	C-B	R-B	Moist tundra		T	X*				X	A*		Flightless chick seen on Thomsen River by Henry, 26 July 1995, and Mico, 12 July 1996.
Baird's Sandpiper *Calidris bairdii*	C-B	U-B	Dryas tundra		T	X*		T	T*	X*	A*		Adults with two fledglings (Henry, 8 July 1995) and young fledglings observed (Raillard, 17 July 1996).
Pectoral Sandpiper *Calidris melanotos*	U-B	U-B	Mesic Tundra		T					X*	A*		Two adults with three flightless young observed (Mico, 15 July 1996).
Buff-breasted Sandpiper *Tryngites subruficollis*	C-B	R-B	Mesic to wet tundra		X	X*		T		X	A*		Four eggs in nest (Henry, 27 June 1995); flightless young observed (Henry, 26 July 1995)
Red-necked Phalarope *Phalaropus lobatus*	U-B	R-SR	Wet tundra		X					X	A		Male and female observed on tundra ponds near Thomsen River and Nangmagvik Lake (Henry and Mico, 14 July 1996)
Red Phalarope *Phalaropus fulicaria*	C-B	R-B	Wet tundra		T	X*	T	T	T	X	A*		Nest found on Eames River (Henry, July 10 1995)
Pomarine Jaeger *Stercorarius pomarinus*	C-B	R-SR	Sedge tundra, mesic tundra		T	X				X	A		Probably depends on lemming cycle

continued

Appendix (*continued*). Species/breeding record list from Banks Island and Aulavik National Park.

Species	Banks Island	ANP	Habitats where often observed.	Source of Information P	MHM	Mah	K	W	ZKS	CH	HM	O	Remarks
Parasitic Jaeger *Stercorarius parasiticus*	C-B	R-SR		T	X				X	A			
Long-tailed Jaeger *Stercorarius longicaudus*	C-B	C-B	Dryas tundra, mesic tundra	X	T	X*	T	T	T	X	A*		Nest with two eggs (Kudlak, 3 July 1995); most common jaeger in park area
Thayer's Gull *Larus thayeri*	C-B	R-B	Coastal areas	X*	T*					T*			Colony at Cape M'Clure; Cotter et al. (1999) observed a breeding colony in SE corner of Mercy Bay
Glaucous Gull *Larus hyperboreus*	C-B	C-B	Lakes, coasts, rivers		T	X	T	T	T*	X*	A*		Colony at Gyrfalcon Bluff; single pair nests on island in pond (HM); Nest with hatched young observed (Rowland, 8 July 1996)
Sabine's Gull *Xema sabini*	C-B	R-B	Wet tundra		T	X	T	T	T*	X*	A		Adult seen on upper Thomsen River (Harry, July 1995); nests among Brant colonies or on islands (Cotter et al., 1999)
Black-legged Kittiwake *Rissa tridactyla*	H				X								Hypothetical for Banks Island (Manning et al. 1956)
Arctic Tern *Sterna paradisaea*	C-B	U-B	Lakes, rivers, coastal areas		T		T	T	T	X*	A*		Flightless chicks seen on Thomsen River (Henry, 28 July 1995); breeds on Melville Island (Maltby 1978)
Thick-billed Murre *Uria lomvia*	H				X								Hypothetical for Banks Island (Manning et al. 1956)
Dovekie *Alle alle*	H				X								Hypothetical for Banks Island (Manning et al. 1956)
Black Guillemot *Cepphus grylle*	R-SR	NR			X								Sight records at Cape Prince Alfred, 10 August 1952 (Manning et al., 1956)
Snowy Owl *Nyctea scandiaca*	C-B	U-B	Moist to mesic tundra	X	T*	X	T	T*	T	X*	A		Breeding success varies with lemming numbers
Short-eared Owl *Asio flammeus*	A or RB	NR	Mesic to wet tundra		X					X			Accidental or rare breeder in southwestern Banks Island (Manning et al. 1956)
Black-billed Magpie *Pica pica*	A	NR										X	Birds shot at Sachs Harbour 13 May 1972 (Urquhart and Kuyt 1973)
Common Raven *Corvus corax*	C-PR	U-B						T	T	X	A*		Adults with two flightless young near Mercy River (Kudlak, 24 July 1995)
Horned Lark *Eremophilia alpestris*	C-B	C-B	Moist sedge tundra	X	T*	X*	T	T	T*	X	A*		Fledgling that flew very weakly observed (Henry, 13 July 1995)
Tree Swallow *Iridoprocne bicolor*	A	NR										X	Birds found dead at Sachs Harbour, 15 June 1964 (Walkinshaw 1965)
Barn Swallow *Hirundo rustica*	R-SR	NR								X			Observed around Sachs Harbour during the summer of 1992 and 1993 (Cotter et al. 1999)
American Robin *Turdus migratorius*	A	NR										X	Recorded by Parks Canada (2000)

continued

Appendix (*concluded*). Species/breeding record list from Banks Island and Aulavik National Park.

Species	Banks Island	ANP	Habitats where often observed.	Source of Information P	MHM	Mah	K	W	ZKS	CH	HM	O	Remarks
American Pipit *Anthus rubescens*	C-B	R-B	Mesic tundra, sedge tundra		T*			T	T	X*	A		Several birds seen near Mercy River (Catto & Rowland, 26 July 1995); Holyoak (1983) found a nest with eggs on southern Banks Island.
Yellow-rumped Warbler *Dendroica coronata*	A	NR										X	Recorded by Parks Canada (2000)
American Redstart *Setophaga ruticilla*	A	NR			X								Specimen from Sachs Harbour on 19 September 1952 (Manning et al. 1956)
Northern Waterthrush *Seiurus noveboracensis*	A	NR			X								Specimen from Cape Kellet on 11 September 1914 (Manning et al. 1956)
American Tree Sparrow *Spizella arborea*	A or R-B		NR		X								May breed on southern part of Banks Island (Manning et al. 1956).
Chipping Sparrow *Spizella passerina*	A	NR										X	Recorded by Parks Canada (2000)
Savannah Sparrow *Passerculus sandwichensis*	A	NR					T					X	Singing male, Nelson Head 9 June 1974 (Latour and Allison 1976)
Fox Sparrow *Passerella iliaca*	A	NR										X	Sight record from Nelson Head on 24 May 1974 (Latour and Allison 1976).
Harris's sparrow *Zonotrichia querula*	A	NR										X	Photograph, Nelson Head, 15 June 1974 (Latour and Allison 1976).
White-crowned Sparrow *Zonotrichia leucophrys*	A	NR			X								Specimen from Sachs Harbour on 18 May 1953 (Manning et al. 1956).
Dark-eyed Junco *Junco hyemalis*	A	NR			X							X	Specimens from Sachs Harbour (Manning et al. 1956). Sight records from Nelson Head (Latour and Allison 1976).
Lapland Longspur *Calcarius lapponicus*	C-B	C-B	Dryas tundra, sedge tundra	X	T	X*	T	T	T	X*	A*		Common breeder in park area; Henry observed copulation and egg-laying (3 July 1995), first mobile young (15 July 1995) & cession of territorial singing (17 July 1995); first mobile fledgling (15 July 1995)
Snow Bunting *Plectrophenax nivalis*	C-B	U-B	Fellfields, rock barrens	X	T*	X		T	T	X	A*		Common near Gyrfalcon Bluff; fledgling flying weakly (Henry, 14 July 1995); fledgling observed (Raillard, 17 July 1996)
Common Redpoll *Carduelis flammea*	A	NR			X								Sight record from Bernard River on 12 July 1963 (Maher 1964)

Night Surveys of Yellow Rails, *Coturnicops noveboracensis*, and Virginia Rails, *Rallus limicola*, in Alberta using Call Playbacks

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The Yellow Rail (*Coturnicops noveboracensis*) and Virginia Rail (*Rallus limicola*) are inconspicuous and apparently rare species in Alberta. Wide scale, targeted surveys have never been conducted for either species, and virtually nothing is known about their distribution, populations, or other traits in the province. We compiled historical records of Yellow and Virginia Rails and conducted nocturnal field surveys using call playback as a first step in clarifying the status of these species in the province. Sixty-two Yellow Rail and 66 Virginia Rail historical sites were collated, with the majority of records occurring in the central and south-central parts of the province. A total of 431 surveys were conducted at 404 sites between 17 May and 6 July 2000. These sites included 69.4% and 60.6% of historical sites for Yellow and Virginia rails, respectively. We encountered 42 unique Yellow Rails and 59 unique Virginia Rails during the surveys, with only 7.0% and 17.5% of visited historical sites being occupied. Fifteen new sites for Yellow Rails were found. Most notable was the presence of 21 birds on Hay Lake in northwestern Alberta, which is a 450 km extension to the known breeding range. Twenty-three new sites for Virginia Rails were found. Playbacks were more effective at detecting Virginia Rails, as the number of spontaneously calling individuals was lower than was found for Yellow Rails (55.0% vs. 80.4%). Yellow Rails were most likely to be found in seasonal wetlands containing sedge, whereas Virginia Rails occupied a wide variety of semipermanent and permanent wetlands. Yellow Rails were most likely to be found when there was little or no moon, and during the middle (darkest) part of the night. Virginia Rails were found significantly more often when the moon was more than half full and relatively unobscured by clouds. The efficiency of future surveys for these species could therefore be improved by focusing efforts during periods and conditions when birds are most likely to be detected.

Key Words: Yellow Rail, *Coturnicops noveboracensis*, Virginia Rail, *Rallus limicola*, Alberta, call playback surveys, distribution, status.

Rails are inconspicuous and reclusive marsh birds that are more likely to be detected by their calls than to be seen (Godfrey 1986). Given that calling is most likely to occur during hours of darkness, it is not surprising that the life history and population status of many species is poorly understood (Eddleman et al. 1988). Evidence suggests that habitat loss and other pressures have led to the reduction of populations of a number of species in North America (Eddleman et al. 1988). Clarification of population status and a better understanding of the ecology of these species should therefore be a high priority to conservation biologists (Holliman 1977; Eddleman et al. 1988; Tacha et al. 1994).

Three species of rail regularly occur in Alberta. The Sora (*Porzana carolina*) is found in most types of freshwater wetlands, and is a common breeding species throughout the province (Salt and Salt 1976; Semenchuk 1992). The Yellow Rail (*Coturnicops noveboracensis*) which inhabits sedge meadows with little or no standing water (Bookhout 1995) is far less common in Alberta. The species is officially listed as being of "undetermined" status in the province due to a lack of information on population size and trend (Alberta Environment 2000*), and is further designated as being of "special concern" by the Committee on the Status of Endangered Species in Canada (COSEWIC) (Alvo and Robert 1999*, Anonymous 2000*). Alvo and Robert (1999*) documented 40 sites where birds have been known to occur in the province, and speculated that there may be at least 500 breeding pairs in Alberta. The Virginia Rail (*Rallus limicola*), which occupies a broad range of wetland types (Conway and Eddleman 1994; Conway 1995) is also considered to be of "undetermined" status in Alberta (Alberta Environment 2000*). However, the species is common in many parts of its range and is not listed by COSEWIC as being a species at risk in Canada (Anonymous 2000*). A comprehensive compilation of historical records has not previously been attempted in Alberta, but the species was found in only 24 locations in the province during the Alberta Bird Atlas

*See Documents Cited

project in the late 1980s and early 1990s (Semenchuk 1992).

Our current knowledge of the status of Yellow and Virginia rails in Alberta is poor (Pinel et al. 1991), and has been derived from a variety of observations collected over several decades. These data provide no information on the size and distribution of populations occurring in the province during any single breeding season, nor on the persistence of populations at any one site. Furthermore, there is much available habitat that has not been surveyed (Alvo and Robert 1999*), and it is likely that both species are more common than indicated by current information. In this study, we aimed to clarify the status of the Yellow and Virginia rails in Alberta by: (1) identifying sites in the province where the species are known to have occurred; (2) conducting inventories at these sites to determine occupancy by individuals during the breeding season; and (3) locating new potential breeding sites through inventories in suitable habitat. We also attempted to gain a better understanding of the habitat requirements and calling behavior of these species to increase effectiveness of future field studies in the province.

Methods

1. Compilation of Historical Records

We obtained many site records for Yellow Rails from Alvo and Robert (1999*). Records for Virginia Rails, and additional records for Yellow Rails were obtained from the Biodiversity/ Species Observation Database (maintained by Alberta Fish and Wildlife Division and the Alberta Conservation Association), the Alberta Bird Checklist Program and Alberta Bird Atlas database (both administered by the Federation of Alberta Naturalists), known published reports, museum collections, the Breeding Bird Survey database, and through requests for information published in several provincial publications and internet newsgroups.

2. Field Surveys

Yellow Rails have been reported calling in Alberta between 26 May and 28 July, whereas Virginia Rails have been heard as early as 14 May in the extreme south of the province (Pinel et al. 1991). We therefore determined that surveys between 20 May and 25 July would have the best chance of detecting birds if present, and that surveys should begin in the south to capitalize on earlier arrival of birds in that area. Past studies have suggested that the probability of detecting either Yellow or Virginia Rails at an occupied site during a single visit is approximately 75% (Bart et al. 1984; Gibbs and Melvin 1993), which we considered to be reasonable for a reconnaissance-level survey. However, repeat visits were occasionally made to sites if logistically feasible. We attempted to visit most documented sites, although the specific locations of many sites were not well described in available documentation. This was especially true of older records, but also of records from the Alberta Bird Atlas database which were only compiled by 10×10 km^2 squares (Semenchuk 1992). In these cases, we typically surveyed between two and five areas of suitable habitat within five kilometers of the expected location, or within the identified Atlas square. Sites scheduled for nocturnal surveys were usually visited during daylight so that access points could be determined, and general habitat variables recorded (see below). Daytime reconnaissance also allowed identification of new areas of potentially occupied habitat that could be visited during the night.

Nocturnal surveys were conducted between sunset and sunrise, which is the period when rails are most likely to vocalize (Johnson and Dinsmore 1986; Manci and Rusch 1988; Gibbs and Melvin 1993; Bookhout 1995; Robert and Laporte 1997). To increase the probability of detection, playback of conspecific calls was used (Marion et al. 1981; Gibbs and Melvin 1993). Calls used in playbacks were assembled from commercially available sources (Peterson 1992; Brigham, undated), and delivered from portable tape players at a height of approximately 1.5 m and a volume between 80 and 95 db. Although the calling and responsiveness of both Yellow and Virginia rails is apparently not greatly affected by weather (Bart et al. 1984; Gibbs and Melvin 1993), wind and precipitation undoubtedly affect detection distances (Bart et al. 1984). We therefore conducted surveys under a range of conditions, but avoided periods with winds >20 km/hr and heavy rainfall. Surveys consisted of a three-minute listening period, followed by three, 20-second playbacks of Yellow Rail calls ("clicks") separated by 20 seconds of silence, and three, 20-second broadcasts of Virginia Rail calls, also separated by 20 seconds of silence (two sets of descending "grunts" and one set of combined "kadic-kadic" and "kicker" calls, which are the vocalizations most often used in territorial advertisement and mate attraction; see Kaufmann 1983; Conway 1995). A final three-minute listening period followed the playback sequence. In a few cases (<10%), playback of only one species' call was delivered (generally at sites historically occupied by that species, and with no obvious habitat for the other species). The number of birds calling during each of the pre-playback, playback and post-playback was recorded. We recorded air temperature (°C), wind speed (Beaufort scale), the presence of precipitation or fog, cloud cover (%), moon phase (new, < half full, > half full, or full), moon visibility (visible, obscured, or absent) and time of night (early = 22:00 to 23:59 h; middle = 24:00 to 01:59 h; late = 02:00 to 05:30 h) as factors that may influence calling behavior. We also recorded (usually during daylight hours, see above) the dominant vegetation type at the survey

location (cattail, bulrush, sedge, or mixed), and the approximate percentage of major cover types in the wetland (standing emergents, open water, bare ground, shrubs, or trees). In addition, we recorded whether surveyed wetlands were permanent (water present in all years) or semipermanent (dry in some years) based on descriptions on topographic maps, or seasonal (present for only part of the year). Attributes of locations where each species was detected were compared with sites where individuals were apparently absent using Mann-Whitney U-tests or chi-square analyses (Conover 1980).

Results

1. Compilation of Historical Records

We compiled a total of 62 historical sites for Yellow Rails and 66 sites for Virginia Rails in the province, which encompassed at least 95 individual records for Yellow Rails reported between 1914 and 2000, and 90 records for Virginia Rails observed between 1945 and 1999. Although the specific dates of some records were unclear, one location for Yellow Rails and at least five locations for Virginia Rails were known only from individuals encountered on or before 1 May, or later than 31 August. Although there is no information on the timing of migration by these species in Alberta (Pinel et al. 1991), we consider these records to be questionable in terms of identifying historical breeding sites. Overall, the data show that both species have been most commonly encountered in the central and south-central parts of the province, with the range of the Virginia Rail extending slightly further to the southeast, and the Yellow Rail to the northeast (Figure 1). Complete details on individual site records are available in Prescott et al. (2001*).

2. Field Surveys

A total of 431 surveys were conducted between 17 May and 6 July 2000. This total included 17 sites that were visited twice, and five sites that were visited on three occasions during the survey period. A total of 404 unique sites were surveyed, covering most of the province with the exception of the mountain parks and extreme northern and northeastern areas (Figure 2). Calls of Yellow and Virginia rails were played during 398 (92.3%) and 414 (96.1%) surveys, respectively. Forty-three of the 62 (69.4%) historical sites for Yellow Rails, and 40 of the 66 (60.6%) known Virginia Rail sites were visited and checked for the presence of potential habitat.

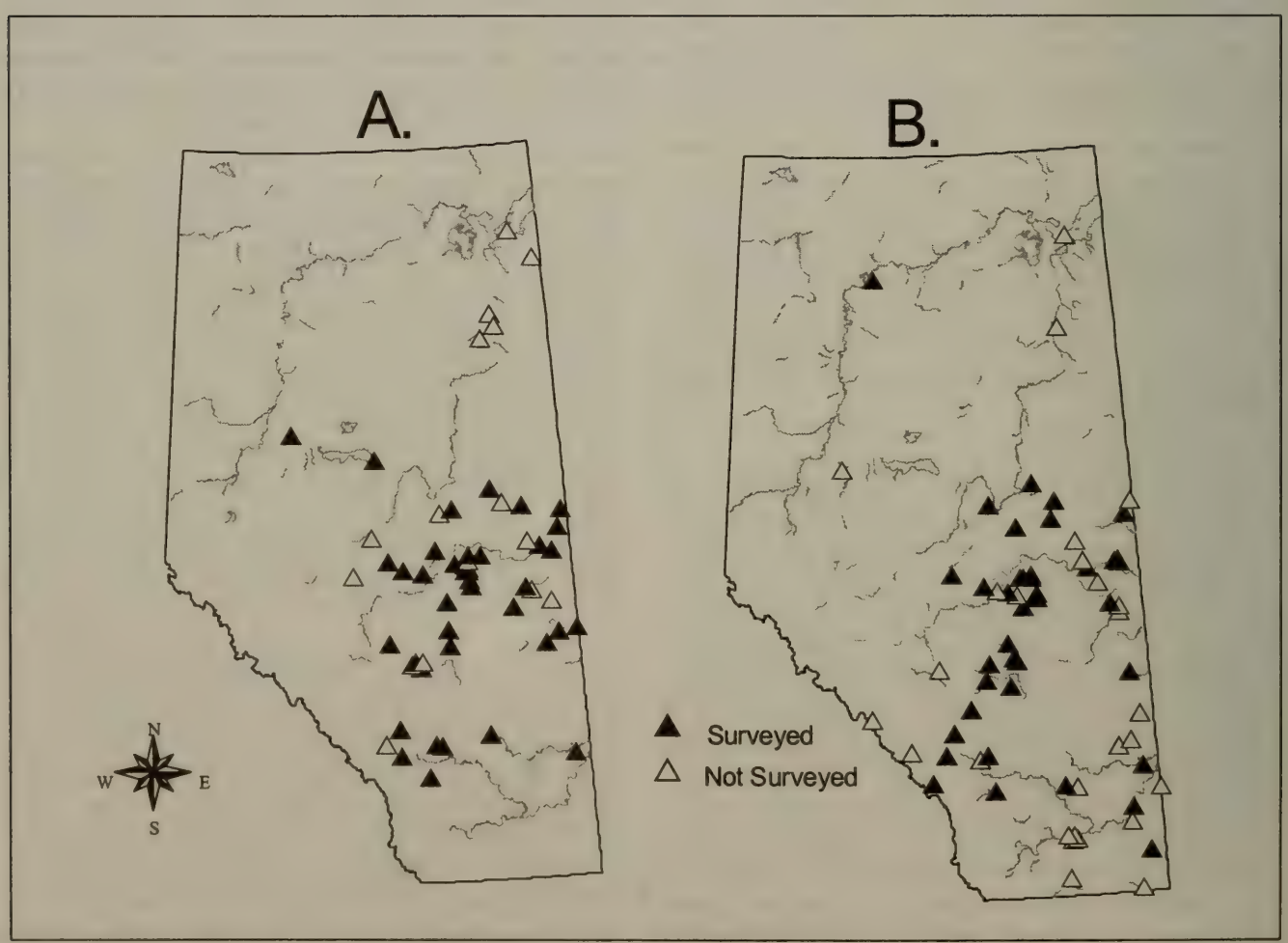

FIGURE 1. Distribution of historical records for Yellow (A) and Virginia (B) Rails in Alberta. See Prescott et al. (2001*) for details. Solid symbols indicate sites that were surveyed using call playbacks during 2000.

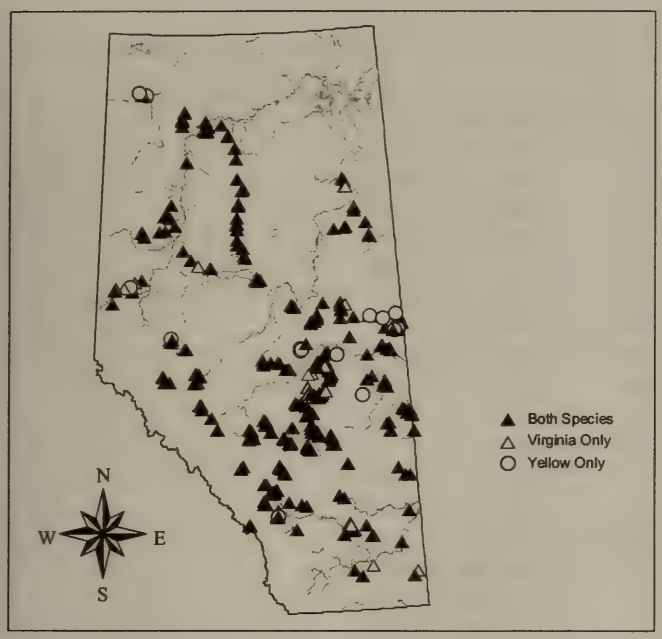

FIGURE 2. Distribution of 404 sites surveyed for calling Yellow and Virginia Rails during 2000. Symbols indicate which call playbacks were delivered at each location.

No suitable habitat could be found at six historical sites (three for each species), so no playback surveys were completed at these locations.

Using only the maximum number of birds heard over all visits to a particular site, we estimate that 42 unique Yellow Rails and 59 unique Virginia Rails were encountered at 18 and 35 sites, respectively. Only three (7.0%) of the visited historical Yellow Rail sites, and seven (17.5%) of the Virginia Rail sites were found to support a total of 5 and 19 individuals, respectively (Tables 1 and 2). However, a minimum of 37 additional Yellow Rails were detected at 15 sites where the species was not previously known to occur. This included 21 birds found at six sites on Hay Lake in extreme northwestern Alberta, about 450 km NNW of the nearest historical location for the species (Kimiwan Lake). We also found an estimated 39 Virginia Rails at 23 sites (24 surveys) at non-historical locations. Only one site was found to contain both species.

The geographical distribution of rails found during the 2000 survey shows a concentration of sites for Virginia Rails in central and southern Alberta (with the exception of one record near La Crete in northwestern Alberta), whereas the Yellow Rail was sparsely and widely distributed from central to northwestern Alberta (Figure 3).

3. Influences on Calling Behavior and Distribution

Of 46 Yellow Rails detected on field surveys (including multiple visits to sites), 37 (80.4%) were calling spontaneously (16 of 20 sites), with an additional nine individuals responding to tape playback. Six of these individuals responded quickly (i.e., during playback), with an additional three birds responding only during the post-playback period. The presence of Yellow Rails at four sites was determined only because of the use of playbacks. At three sites however, birds calling spontaneously stopped calling immediately when tapes were played, and did not start calling again before the session was terminated. Detection of Yellow Rails was influenced by the lunar phase, and birds were most vocal when illumination levels were low. Specifically, birds were found at 12.2% of 49 sites surveyed during a new moon, 4.4% (n = 159) and 2.6 % (n = 114) of sites when the moon was less than and more than half full, respectively, and only 1.4 % (n = 71) of sites visited during a full

TABLE 1. Location and notes on where Yellow Rails were detected during the 2000 survey.

Survey Location[1]	Latitude (°N)	Longitude (°W)	Notes
22 km W of Airdrie	51.325	114.328	2 birds on 2 July
Lochend Lake	51.330	114.321	1 bird on 2 July
5.5 km NE Rocky Mountain House	52.327	114.954	2 birds on 3 July
2.5 km W of Mirror	52.463	113.164	1 bird on 17 June
Spotted Lake (*)	52.487	113.133	3 birds on 31 May, 1 bird on 4 June (daytime)
Reflex Lake (*)	52.660	110.027	1 bird on 22 June
17 km WSW of Edson on Hwy 16	53.543	116.668	2 birds on 28 June
1.5 km NE of Angling Lake	54.228	110.204	4 birds on 22 June, 3 birds on 23 June
7.2 km NNE of Slave Lake (*)	55.346	114.726	1 bird on 30 June. Also 2 Virginia Rails at this site
Buffalo Bay	55.563	116.273	1 bird on 30 June
198 km N of Red Earth	58.049	115.612	2 birds on 6 July
Lost Lake	58.345	116.402	1 bird on 5 July
NE Shore of Hay Lake	58.833	118.633	1 bird on 5 July
	58.832	118.628	3 birds on 5 July
	58.832	118.621	5 birds on 5 July
	58.833	118.648	5 birds on 5 July
	58.826	118.697	1 bird on 5 July
	58.864	118.871	6 birds on 5 July

historical site listed in Prescott et al. (2001)

TABLE 2. Location and notes on where Virginia Rails were detected during the 2000 survey.

Survey Location[1]	Latitude (°N)	Longitude (°W)	Notes
Prince's Spring (*)	50.813	110.344	1 bird on 30 May
	50.808	110.341	1 bird on 30 May
6.5 km S of Priddis	50.848	114.325	1 bird on 5 June
15 km NNE of Oyen	51.472	110.355	2 birds on 14 June
0.5 km N of Barrie Lake (*)	51.766	114.191	3 birds on 16 June
	51.780	114.193	4 birds on 16 June
North of Barrie Lake	51.783	114.191	1 bird on 16 June
15 km S of Delburne (*)	52.061	113.219	1 bird on 16 June
11 km WSW of Lousana	52.095	113.338	1 bird on 16 June
3.5 km SE of Alix	52.383	113.145	4 birds on 16 June
6 km E of Alix	52.405	113.096	1 bird on 17 June
0.8 km E of Gabriel Lake	52.426	114.410	1 bird on 19 June
2 km NW of Lacombe (*)	52.485	113.764	1 bird on 17 June
	52.491	113.749	1 bird on 17 June
Ribstone Creek	52.488	110.740	3 birds on 21 June
6 km W of Chauvin	52.700	110.221	2 birds on 21 June
1 km W of Ribstone	52.722	110.281	1 bird on 21 June
1 km SW of Samson Lake (*)	52.727	113.262	3 birds on 19 June
	52.714	113.282	1 bird on 19 June
	52.720	113.284	2 birds on 19 June
Bearhills Lake	52.960	113.626	1 bird on 19 June. Not heard on previous night
2 km W of Camrose	53.018	112.881	2 birds on 22 June
8 km NW of Camrose	53.055	112.953	1 bird on 22 June
1 km NE of Bittern Lake village	53.105	113.028	2 birds on 23 June
8 km N of Camrose	53.109	112.825	1 bird on 27 June
21 km NE of Camrose	53.193	112.680	1 bird on 27 June
5.5 km NW of Big Hay Lake	53.234	113.221	1 bird on 22 June
8 km W of Mannville	53.321	111.305	2 birds on 22 June
Tawayik Lake Marsh, Elk Island National Park	53.618	112.874	2 birds on 26 June
Elk Island National Park, S of N gate (*)	53.700	112.809	1 bird on 22 June
1.8 km NE of Angling Lake	54.241	110.204	1 bird on 22 June, 3 birds on 23 June
0.5 km S of Cherry Grove	54.332	110.079	3 birds on 21 June
7.2 km NNE of Slave Lake	55.346	114.726	2 birds on 30 June. Also 1 Yellow Rail at this site
	55.307	114.752	1 bird on 30 June
3.5 km SW of La Crete (*)	58.155	116.376	1 bird on 5 July

historical site listed in Prescott et al. (2001)

moon ($\chi^2 = 9.7$, df = 3, $p < 0.05$). Rails were also found more frequently during the middle of the night (24:00–01:59 h) than during earlier or later periods ($\chi^2 = 8.2$, df = 2, $p < 0.05$). Although these patterns suggest that darkness is a factor in calling behavior, detection was not influenced by whether the moon was visible, obscured or absent during a survey ($\chi^2 = 0.31$, df = 2, $p > 0.8$). There was also no apparent influence of any other meteorological variables (wind, precipitation, cloud, fog or temperature; all $p > 0.4$) on encounters with Yellow Rails.

Spontaneously-calling Virginia Rails were detected at 23 sites (total of 33 birds, or 55.0% of all encounters). Responses to tapes were generally stronger than for Yellow Rails. An additional 27 birds were detected through playbacks, with 22 of these responding immediately. Thirteen sites for Virginia Rails were identified only through responses to playbacks. At five sites, however, birds (six individuals) that were already vocalizing became quiet upon delivery of the playback. Calling by Virginia Rails was influenced by the moon phase ($\chi^2 = 11.2$, df = 3, $p < 0.01$), but in the opposite pattern to Yellow Rails. Birds were most likely to be found during a full moon (13.9 % of 72 sites surveyed) or periods when the moon was more than half full (13.5% of 159 sites), and least likely when the moon was less than half full (4.4% of 126 sites) or during a new moon (3.9% of 52 sites). Birds also were detected more often on nights when the moon was visible or obscured, as opposed to being absent ($\chi^2 = 10.2$, df = 2, $p < 0.01$). Cloud cover, precipitation and time of night did not differ between sites where Virginia Rails were considered present or absent, although temperatures during surveys when birds were detected were lower than when no birds were found (8.8 ± 0.6°C vs. 10.0 ± 0.2°C; $T = 2.2$, $p < 0.05$).

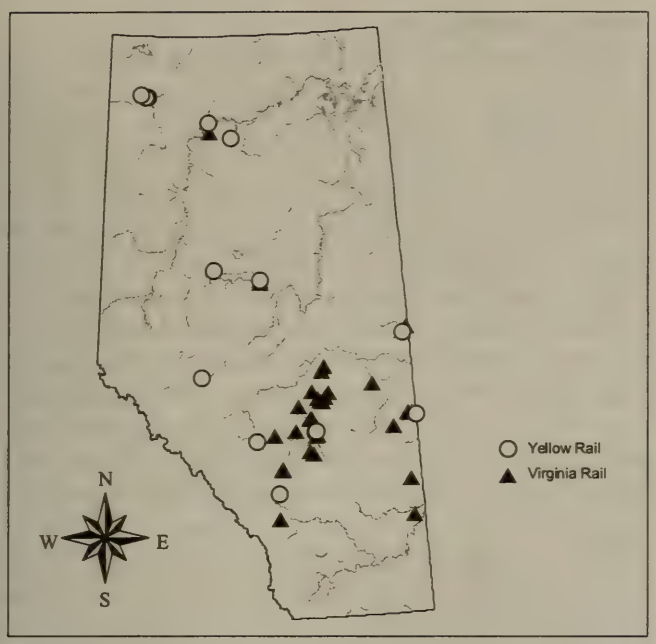

FIGURE 3. Sites where Yellow and Virginia Rails were found during call playback surveys in 2000. See Tables 1 and 2 for additional details.

Yellow Rails were detected significantly more often than expected in sedge and "mixed" (cattail/bulrush/sedge) wetlands, and less often in basins dominated by cattail or bulrush ($\chi^2 = 8.4$, df = 3, $p < 0.05$). Furthermore, occupied basins were most likely to be seasonal, as opposed to semipermanent or permanent ($\chi^2 = 6.7$, df = 2, $p < 0.05$), and tended to have less open water (10.6 ± 4.4 [SE]%) than sites where birds were not detected (24.8 ± 1.5 %; T = 2.8, $p < 0.005$). Virginia Rails showed no preference for basins dominated by particular vegetation types ($p > 0.4$), but preferred wetlands with more open water (32.1 ± 4.5% vs. 23.5 ± 1.6%; T=2.2, $p < 0.05$) and less shrub (5.1 ± 1.3 vs. 9.9 ± 0.8; T = 1.9, $p < 0.06$). Furthermore, birds were found more often on permanent or semipermanent wetlands than on seasonal waterbodies ($\chi^2 = 5.9$, df = 2, $p < 0.06$).

Discussion

Our results support previous descriptions of Yellow and Virginia rails being widely distributed but relatively uncommon species in Alberta (Salt and Salt 1976; Pinel et al. 1991; Semenchuk 1992; McGillivray and Semenchuk 1998). In general, these references identify the central areas of the province as being the areas of highest density, which is consistent with the distribution of historical records that we compiled. We caution, however, that higher numbers of human observers and higher road density likely bias the distribution of historical records in that part of the province, and that the species' historical occurrence in other parts of the province may be underestimated.

We focused our field surveys around historical sites, and therefore many of the previously unsurveyed areas tended to be near, or between historical locations. It is therefore not surprising that the majority of encounters with rails (and especially Virginia Rails) in 2000 occurred in the central part of the province as well. The distribution of Yellow Rails was less closely matched to historical records, with field surveys revealing a relatively sparse distribution from central to northwestern Alberta. The records in the northwest were especially notable, as they represent a major extension of the known range of this species. In fact, almost half of all Yellow Rail encounters in 2000 were at six sites on Hay Lake. Those sites represent a very small fraction of the available habitat in the Hay-Zama Lakes area (K. Wright, Alberta Conservation Association, personal communication), and the region has the potential to support many more birds than we encountered. This is also true for the northeastern part of the province, which has poor road access and was not well surveyed in 2000. Although Virginia Rails have never been reported from northeastern Alberta, there are several historical records of Yellow Rails from the area north of Fort McMurray, and from adjacent areas of the Northwest Territories (see Alvo and Robert 1999*). The Peace-Athabasca Delta, which has one historical Yellow Rail record, contains large areas of wet sedge (M. Bradley, Parks Canada, personal communication) and has the potential to support large numbers of breeding rails. We also did not survey potential habitat in Jasper and Banff National Parks. These areas have historical records for both Yellow and Virginia rails, although none of these occurred with certainty during the breeding season (Prescott et al. 2001*). However, there are several records of both species during the breeding season from adjacent areas of British Columbia (Campbell et al. 1990), which suggests that the mountainous areas of Alberta should be considered for surveys in the future.

Of approximately 400 surveys conducted for each species, we found Yellow and Virginia rails at only 18 and 35 sites, respectively. Furthermore, 12 (66.7%) of the Yellow Rail sites and 29 (82.9%) of the Virginia Rail sites contained only a single calling bird (Tables 1 and 2). Values for both the number of sites occupied and the number of calling birds at each site are likely underestimates, as > 90% of all the sites were only visited on a single occasion which would have detected occupancy with no better than 75% certainty (Bart et al. 1984; Gibbs and Melvin 1993). Nevertheless, it is apparent that both species of rails are relatively uncommon within their Alberta range. Occupancy rates at historical sites were also low. This is especially true of Yellow Rails (three of 42 sites surveyed), and may reflect the observed preference of birds for seasonal wetlands ([see also Boukhout (1995) and references therein)] which can vary greatly in condition from

year to year depending on local precipitation. Return rates by breeding birds might therefore be even lower than the 5.4% reported by Robert and Laporte (1999) for relatively stable estuarine habitats in eastern Quebec. Seasonal wetlands on the prairies are also most likely to be impacted by agricultural activities such as cultivation, drainage, and cattle grazing (several historical areas visited in 2000 were dry, and being grazed). In contrast, Virginia Rails were found most often in permanent or semipermanent wetlands, where habitat suitability is more stable over time, and which are less likely to be altered by human activities. Evidence suggests that Virginia Rails will return to sites in successive years if habitat conditions remain stable (Mousley 1931; Conway 1995), and the higher occupancy of historical sites we observed (seven of 39) may reflect this stability. The relatively low occupancy rate of both species suggests caution must be exercised in using compilations of historical data collected over many years to assess population status of these species (e.g., Alvo and Robert 1999*).

Attempts to inventory Yellow and Virginia rails in Alberta have been scant (Pinel et al. 1991; Semenchuk 1992), and our surveys represent the first focused effort to determine the distribution and status of these species in the province. However, there remain several key areas of the province that were not surveyed, and much suitable habitat in all parts of the province that could not be visited. Clarification of the status of these species therefore demands additional survey effort from biologists. However, we recommend that additional large-scale inventories be preceded by research into factors affecting calling behavior of these two species. Of particular interest is our observation that Yellow Rails tended to be found during periods with little or no moon (and during the darkest part of the night), and that Virginia Rails tended to be found during periods where the moon was more than half full and the sky was relatively clear. Although we hesitate to place strong emphasis on patterns resulting from an observational study with a relatively small sample of occupied sites, the results suggest that the survey protocol could be refined to focus efforts during periods when birds are most likely to be detected. Furthermore, if the probability of detecting spontaneously-calling birds could be increased, the use of call playbacks could be eliminated. This would reduce the amount of time required to inventory each area, and allow many more locations to be surveyed in a single field season. Our surveys in 2000 have identified a number of sites where season-long monitoring of calling behavior could be conducted, and we intend to initiate intensive surveillance of selected sites in 2001.

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The Gray Wolves, *Canis lupus*, of British Columbia's Central and North Coast: Distribution and Conservation Assessment

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The Gray Wolves (*Canis lupus*) of coastal British Columbia are a remnant group of a much larger population that once inhabited most of North America, including its west coast temperate rainforests. During summers 2000 and 2001, we surveyed 36 islands and 42 mainland watersheds on British Columbia's Central and North Coast for the presence of wolves. An extensive survey had not been conducted previously. We observed wolf sign at all locations, including islands or island groups separated by approximately 7, 8, and 12-km from other large landmasses. The distribution of wolves on islands may be dynamic, with occupancy by solitary Wolves or packs being ephemeral. The potential for an island to support a persistent population of wolves may depend on the presence and abundance of their main prey, Black-tailed Deer (*Odocoileus hemionus*), and security from exploitation by humans. These factors likely are mediated by island isolation, area, shape, topography, and extent of logging. Mounting evidence suggests that logging negatively affects Wolves in temperate rainforests by reducing carrying capacity for deer.

Key Words: Gray Wolf, *Canis lupus,* distribution, islands, British Columbia, logging, conservation.

The Gray Wolf, *Canis lupus*, is one of the most intensely studied wildlife species in North America, yet complete and recent distributional data are absent from the large and remote Central and North Coast of British Columbia (Figure 1). The equilibrium theory of island biogeography predicts that species composition on islands is a function of immigration and extinction, mediated by island area and isolation (MacArthur and Wilson 1967). The ability of a terrestrial mammal to colonize islands depends on degree of isolation, the species' swimming ability, and water conditions.

Earlier, it was postulated that the occurrence of Gray Wolves on the islands of coastal British Columbia and Alaska was a function of the presence of their main prey, Black-tailed Deer (*Odocoileus hemionus*), but limited by isolation on islands to which wolves were capable of swimming (McCabe and Cowan 1945; Klein 1965). MacDonald and Cook (1996) stated that Gray Wolves occurred in all mainland areas and on most islands of southeast Alaska, but not on small and isolated ones without adequate prey. Nagorsen (1990) described Gray Wolf range in British Columbia as comprising the "entire mainland, Vancouver Island and some adjacent islands". Our main objective herein is to describe the distribution of Gray Wolves along the Central and North Coast of British Columbia, particularly on islands. We also discuss conservation concerns relevant to wolves of coastal temperate rainforests because these factors may influence future distribution (Person et al. 1996*; Darimont and Paquet 2000*; Person 2000). We recorded the information while conducting field studies of wolves and their prey during summers 2000 and 2001 (Darimont and Paquet 2000*; Darimont and Reimchen 2003; Darimont et al. in press).

Methods

Study Area

Boats and airplanes provide the only access to this nearly roadless and mostly unsettled region. Extensive fjords divide mainland valleys. Tidal waters separate islands that vary from < one km^2 to > 2,200 km^2 (Princess Royal Island). Inter-island and mainland-island distances range from several metres to approximately 13-km. The study area was roughly delineated by the Kshwan Valley (55° 37′ N, 129° 48′ W) in the north to Cape Caution (51° 10′ N, 127° 47′ W) in the south, and oriented parallel to the coastline (Figure 1). The Coast Mountains and the Pacific Ocean bound the study area to the east and west respectively.

Most of the low elevation forest is within the Coastal Western Hemlock biogeoclimatic zone (*sensu* Krajina 1965), characterised by a wet and temperate climate. Annual precipitation exceeds 350 cm in most areas. Thirty-year average annual snowfall measured near sea level varies from 86 cm (Bella Bella) to 155 cm (Ocean Falls) (Environment Canada 1991*).

*See Documents Cited section.

FIGURE 1. Study area, survey sites, and other notable landmarks relevant to survey for Gray Wolf distribution on British Columbia's Central and North Coasts during summers 2000 and 2001.

Snowfall is much greater in the inland and higher elevation portions of the study area but no weather data exist. Prey species available to wolves include Black-tailed Deer, Beaver (*Castor canadensis*), River Otter (*Lutra canadensis*), other mustelids, birds, and small rodents. Moose (*Alces alces*) inhabit the eastern fringes

of the study area. Mountain Goats (*Oreamnos americanus*) are found on the mainland, but presence has been confirmed on only Pitt and Princess Royal Islands (Nagorsen and Keddie 2000). Marine foods such as spawning salmonids (Darimont and Reimchen 2002; Darimont et al. *in press*, and Paquet, unpublished) and beached marine mammals are also available. Possible competitors are Brown Bear (*Ursus arctos*) and Black Bear (*U. americanus*), Wolverine (*Gulo gulo*), Coyote (*Canis latrans*), and Cougar (*Felis concolor*).

Environmental conditions that may influence movements of wolves among landmasses vary seasonally and geographically. The following information is summarised from Thomson (1981). Mean air and water temperatures are lower during winter than summer, and average wind speed and wave height are greatest during fall and winter and in outer coastal areas. Surface currents flood primarily to the northeast and ebb to the southwest, but are consistently modified by wind, runoff, bathymetry and shoreline configuration. Typically, current velocity increases in narrow waterways. Fog is most common during summer and on the outer coast.

We used a Geographic Information System (ArcView 3.2 — Environmental Systems Research Institute Inc.) to calculate island areas from 1:20 000 forest inventory maps (Province of British Columbia) generalized to 1:250 000. Minimum shore-to-shore distances at low tides were calculated from marine charts (Canadian Hydrographic Service). We indexed isolation as the shortest island-to-mainland distance or sum of island-to-island distances (excluding distances across islands) to mainland for outer islands (Conroy et al. 1999). We also measured minimum distances to other large landmasses (>75-km^2). We used 75 km^2 as a threshold area because that is about the size of Coronation Island, southeast Alaska, on which some wolves among an initial introduced population of four survived in isolation for eight years (Klein 1996).

Sampling

We selected sampling sites that were well distributed throughout the study area and where we considered moorage safe. At each location, we used sandy beaches, estuaries, and forests of the beach fringe to begin our search for wolf sign. Wildlife trails, often next to watercourses, allowed travel inland. We also surveyed logging roads when encountered and often circumnavigated Beaver ponds and other wetlands. In addition, we walked forest ridgelines. Our surveys rarely extended greater than 5 km inland. Survey effort differed at each location from a few hours to several days.

We determined presence of wolves by noting tracks, scat, sightings, and carcasses. We did not systematically solicit howling but recorded all vocalizations. Wolves are the only canid known on coastal islands in the region, although Red Foxes (*Vulpes vulpes*) and Coyotes occur on the mainland (Nagorsen 1990). Coyote tracks can be distinguished from wolf tracks based on differences in size (Rezendes 1999). Scats from Coyotes are generally smaller than scats from wolves, although there is some overlap in size (Weaver and Fritts 1979). Although the probability in this remote area is low, we may have assigned Gray Wolf presence to the tracks or scats of large feral Dogs (*Canis familiaris*).

Results

We observed recent wolf sign in all mainland watersheds (n = 42), confirming a continuous north-south distribution on the coastal mainland. Thirty-four of 36 islands had recent Gray Wolf sign. The most isolated islands on which we noted Gray Wolves were Moore Island, the Goose Group, and adjacent Dundas/Dunira Islands at 5 km, 7 km, and 12/13 km respectively from other large landmasses (Figure 1; Table 1).

We found scats and tracks at all survey locations (n = 78) except the Goose Group and Moore Island, where no tracks were observed (Table 1). We found remains of dead wolves at three island sites and observed wolves on the shoreline at several mainland rivers and on six islands (Table 1). Howling was heard at some sites (Table 1).

On the Goose Group of islands (~25 km^2), we observed extensive sign of deer and found one old scat from a wolf. A Steller Sea Lion (*Eumetopias jubatus*) carcass showed no evidence of scavenging by large mammals. On the Moore Islands, which comprise a very small (<5 km^2) archipelago, we recorded no sign of deer. However, we found one old scat containing bird and other unidentified material. In contrast, we noted deer sign and fresh wolf tracks and scat on Dundas and Dunira Islands, which are relatively large but extremely isolated adjacent islands at least 12 km from other large (or any habitable) landmasses (Table 1).

Discussion

The current distribution of wolves in coastal British Columbia ranges from the deepest inlets of the coastal mountains to the most remote of islands (Figure 1; Table 1). The presence of wolves at all mainland survey sites concurs with earlier reports of the species' distribution along the Pacific Coast (Nagorsen 1990; MacDonald and Cook 1996).

Notably, of the 17 islands surveyed by both studies, we detected the presence of wolves on six islands that McCabe and Cowan (1945) did not. These discrepancies likely reflect an artifact of sampling effort (ours being greater and more focused), or perhaps (re)colonization. Wolf and deer sign was detected on the Goose Group, where Guiguet (1953), after completing a four-month ecological inventory, reported neither species. Deer may have colonized the group since then (either naturally or assisted by humans).

TABLE I. Island areas (km^2) and distances (m) from mainland and islands greater than 75 km^2 for island sampling sites on the Central and North Coast of British Columbia, Canada where Gray Wolves or their sign were observed. ca = carcass, ho = howling, ob(x,y) = observation (number seen at x location and at a different y location), sc = scat, tr = tracks. N/A = not applicable (i.e., island is closer to mainland than other landmasses). Sampling site codes match those in Figure 1.

Island	Sampling Site	Sign Observed	Area (km^2)	Distance to Mainland (m)	Distance to Island > 75 km^2 (m)
Pearse	9	ob(3),sc,tr	226	300	N/A
Wales	11	sc,tr	97	700	350
Dundas	13	sc,tr	160	12000	N/A
Dunira	15	sc,tr	22	13050	1700
Stephens	16	sc,tr	78	3100	700
Lewis	17	ob(2),sc,tr	7	2400	100
Porcher	18	sc,tr	632	2300	1900
McCauley	19	sc,tr	273	1050	650
Anger	26	ho,ob(1),sc,tr	51	600	200
Hawkesbury	29	ca,ho,ob(2),sc,tr	322	1950	1550
Banks	30	sc,tr	1024	3250	2200
Pitt	31	ho,ob(3,1),sc,tr	1349	400	N/A
Farrant	32	ho,ob(4,1),sc,tr	50	450	50
Gribbell	33	sc,tr	207	1550	1550
Fin	38	sc,tr	13	2250	1750
Gil	40	sc,tr	238	3900	2050
Dewdney	41	sc,tr	37	6200	100
Compania	42	sc,tr	157	2450	2050
Princess Royal	47	ca,sc,tr	2295	900	50
Moore	49	sc	5	12500	8000
Aristazabal	50	sc,tr	451	4350	3450
Pooley	51	sc,tr	162	250	100
Roderick	53	sc,tr	239	350	100
Yeo	59	ob(1),sc,tr	95	250	N/A
Chatfield	60	sc,tr	48	1000	100
Athlone	62	sc,tr	40	2800	1350
Dufferin	63	sc,tr	43	2750	1300
Horsfall	64	sc,tr	32	2650	1250
Cunningham	65	sc,tr	115	850	150
Stryker	66	sc,tr	10	2800	1400
Campbell	67	ca,sc,tr	145	1450	400
Denny	68	sc,tr	127	1000	150
King	69	sc,tr	826	1750	N/A
Goose Group	70	sc	24	8700	7250
Hunter	71	ob(1),sc,tr	399	1700	700
Calvert	73	sc,tr	326	3850	3100

The presence of wolves on extremely isolated islands suggests that the potential for wolves to swim among landmasses is high. The ocean, however, likely serves as a considerable barrier to movement. Previously, Gray Wolves have been described as good swimmers, but only of short distances in fresh water (Mech 1970; Pimlott et al. 1969*; Nelson and Mech 1984; Coscia 1993). Swimming in marine environments probably carries considerably more energetic costs than travel on land, and may impose costs by elimination (e.g., drowning). Moreover, the effects of currents, which vary between landmasses, may be as important as straight-line distances in influencing movement (Cameron 1958; Williamson 1981). Finally, sightability [visibility] may affect orientation (MacArthur and Wilson 1967) and influence which islands wolves select, especially during foggy periods of summer.

Radio-telemetry data from southeast Alaska confirm that dispersal across large water bodies is possible but infrequent. Person (2000) documented wolves swimming at least 2 km, although none of 11 dispersing animals left Prince of Wales or adjacent islands during three years of study. Although low prey density can stimulate dispersal (Peterson and Page 1988; Fuller 1989), presumably starving wolves on Coronation Island, southeast Alaska, failed to swim 900 m to a nearby island where deer were available (Klein 1996).

Due to the barrier effects of water, some populations on islands are probably independent sub-populations among which exchanges of individuals or

packs are limited. We were not able to determine if the wolf sign found on islands came from multiple or solitary animals, or whether Wolves were resident or transient. Future studies may benefit by examining the presence, movements, and demographic fates of individuals over time to examine if metapopulation theory is applicable; such frameworks for other large mammals in habitat patches have been developed (e.g., Elmhagen and Angerbjörn 2001).

Occupancy by Gray Wolves on islands likely is influenced by the presence and abundance of deer, and security from exploitation by humans. These factors might be mediated by size of island, isolation, topography, shape, and extent of logging. Because wolves are obligate predators of ungulates, islands without deer would not sustain wolves. Persistence times, however, are probably a function of the abundance and availability of deer (Fuller 1989) as well as island size and isolation. Wolves seem unable to persist indefinitely on small and isolated islands, even if deer are present. On isolated islands, they may be subject to a "minimum area effect" (*sensu* Lomolino 1986). That is, although their immigration potential is high, they can only maintain populations on the largest of isolated islands.

In the 1960s, biologists introduced four Gray Wolves to the 73 km^2 Coronation Island, southeast Alaska, 900 m from another landmass, to study the effects on resident deer (Klein 1996). After reaching a peak of 13 animals in four years, the wolf population, having severely reduced deer numbers, plummeted to one. Klein (1996) and Person et al. (1996*) stated that small and isolated islands, such as Coronation, are unable to support populations of wolves. Person (2000) noted that islands as large as 180 km^2 with deer carrying capacities greater than 2500 in southeast Alaska did not continuously support wolves between 1955 and 2000.

Lamolino (1986) argued that extinction-prone species, such as large carnivores, might be common on small islands only if their immigration rates are high relative to extinction rates. This can apply to Gray Wolf packs as a conceptual unit. The social group may be sustained if their home range includes a collection of nearby islands (Klein 1996; Person et al. 1996*; Person 2000). Including multiple landmasses would compensate for extirpation risk on individual islands. Of the four most isolated islands on which we noted sign, wolves currently were present only on Dundas and Dunira Islands (Figure 1; Table 1), and probably formed one social group. Although both are isolated from large landmasses, collectively these and smaller nearby islands total 239 km^2, an area within the range of home ranges calculated for wolves of southeast Alaska (Person 2000).

The viability of wolves on large but isolated islands or island groups such as Dundas and Dunira may be uncertain. For example, although the 540 km^2 Isle Royale has supported wolves since the late 1940s without further immigration, the population has experienced considerable declines due to disease, demographic stochasticity, and shortage of food (Peterson and Page 1988; Vucetich et al. 1996; Peterson et al. 1998). Moreover, continued viability may be threatened by a loss of genetic diversity (Wayne et al. 1991).

In coastal British Columbia, an island's topography would interact with size and isolation in determining the abundance of deer and thus the viability of wolf populations. The complex topography of many inner coastal islands can include elevations of 1100-m or more, above which deer in adjacent southeast Alaska are not known to occur (Schoen and Kirchhoff 1985). Thus, habitat suitable for deer and wolves can be less than predicted based on area alone.

Mounting evidence suggests that carrying capacity for deer will be reduced by even age stand management in the Pacific Northwest because clearcut logging is largely incompatible with the food requirements of deer (Wallmo and Schoen 1980; Alaback 1982; Rose 1982; Alaback 1984*; Schoen et al. 1984, 1998; Van Horne et al. 1988; Hanley et al. 1989*). Most notably, closed canopies that develop 20–30 years after harvest severely limit forage for deer and persist for 140–160 years (Wallmo and Schoen 1980; Alaback 1982; Schoen et al. 1988).

Persistence on islands might also be influenced by human-caused mortality. Island wolf populations are vulnerable to over-exploitation because water bodies may slow immigration and re-colonization (Person et al. 1996*; Person 2000). Person (2000) reported that humans on Hecata Island, southeast Alaska, nearly exterminated Gray Wolves on two occasions. In our nearly roadless study area, the shape of islands may affect human-caused mortality. Coastlines are analogous to roads because travel routes of human hunters in boats and wolves converge. Because of high coastline to interior ratios, long and narrow islands provide less security than rounder islands.

Although annual human-caused mortality in the study area is only about 2 %, the human population is growing considerably and hunting regulations are liberal (Darimont and Paquet 2000*). Moreover, more road building is planned to support industrial logging (Darimont and Paquet 2000*). This is a concern, as many authors have shown the lethal impact of roads on Wolves (i.e., Thiel 1985; Jensen et al. 1986; Fuller 1989; Paquet et al. 1996*; Callaghan 2002) and other wildlife species (*review in* Trombulak and Frissell 2000).

We encourage others to invoke a broad spatial and temporal perspective when considering the distribution and conservation status of this population of Gray Wolves, regardless of their wide distribution in the study area now. Extant populations, such as those in coastal British Columbia, form remnant groups of those that first colonized North America roughly 700 000 years ago (Nowak 1979; Kurten and Anderson 1980) and historically ranged in every habitat that

supported ungulate prey. During the last few hundred years, humans have reduced Gray Wolf populations and effectively isolated them to remote areas of Canada, Minnesota, and Alaska (Mech 1970, 1995). On the West Coast, wolves were extirpated in California, Oregon, and Washington, as well as in the Lower Mainland region of British Columbia (Theberge 1991). Wolves of these coastal rainforests are now restricted to southeast Alaska and most of British Columbia. Furthermore, coastal biota, including the Gray Wolf, is thought to be at least partially isolated from continental populations by coastal mountain ranges (e.g., McCabe and Cowan 1945; Klein 1965; MacDonald and Cook 1996; Person et al. 1996*; Byun et al. 1997; Conroy et al. 1999; Darimont and Paquet 2000*; Cook and MacDonald 2001; Figure 1). Finally, wolves of coastal British Columbia should be considered a natural source population for those in nearby southeast Alaska, a population for which there is considerable conservation concern due to timber removal and associated effects (Kirchhoff 1991*; Person and Ingle 1995*; Person et al. 1996*; Person 2000)

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A Review of the Status of the Atlantic Wolffish, *Anarhichas lupus,* in Canada*

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The Atlantic Wolffish, *Anarhichas lupus* Linneaus, 1758, is a large blenny-like marine fish found in moderately deep and cold waters of the North Atlantic on rocky and hard bottoms from the Gulf of Maine to northwestern France. Wolffish was once the target of a directed fishery, but is not at present; nonetheless, it continues to be taken incidentally as by-catch in the trawl fishery. In Canadian waters, it has been most abundant off Newfoundland and Labrador, where it is a characteristic member of the deep cold-water fish assemblage on the continental shelf, but its numbers there, as indicated by scientific surveys, declined by 91% between 1978 and 1994. In other Canadian areas, where wolffish abundance has historically been lower by about an order of magnitude, populations appear stable. Wolffish are relatively sedentary and slow-growing. They make nests, and guard their large eggs. They feed mostly on bottom invertebrates. Life histories and distribution patterns can vary considerably across the species's range. Aggressive trawl fisheries, now in abeyance by the imposition of widespread moritoriums, appear to have had an impact on wolffish numbers. In the Newfoundland region, numbers have declined steadily in scientific surveys, the number of locations where the species occurs is fewer, the range where abundant appears to be shrinking, and the mean size has decreased so that mature individuals have become relatively rare. Slow growth, fidelity and inshore nesting habit, and limited dispersal make rescue unlikely, and bottom trawling and dredging have probably damaged habitat.

Key Words: Atlantic Wolffish, *Anarhichas lupus,* North Atlantic, population size, status, Newfoundland, Labrador.

The wolffishes, family Anarhichadidae, are large blenny-like marine fishes which inhabit moderately deep waters of the North Atlantic and North Pacific oceans. They are named for the characteristic large, conical, canine-like teeth employed in consuming the benthic crustaceans and invertebrates which are their chief food source. Three species of wolffish occur in the Canadian Atlantic area: the Northern Wolffish (*Anarhichas denticulatus* Krøyer, 1844), the Spotted Wolffish (*Anarhichas minor* Olafsen, 1774), and the Atlantic Wolffish (*Anarhichas lupus* Linnaeus, 1758).

The Atlantic Wolffish is an elongate, laterally compressed fish with a heavy head, blunt snout and rounded profile. It can reach a length of 150 cm and a weight of almost 20 kg. In common with all wolffish, it has distinctive and prominent large canine-like teeth in the front of the jaws and flattened, grinding teeth behind. There are no pelvic fins. Atlantic Wolffish vary in colour, depending on their surroundings, from slaty blue to dull olive green to purplish brown, and there are dark transverse bars on the body (Whitehead et al. 1986; Scott and Scott 1988).

The Atlantic Wolffish can be distinguished from the other two wolffishes of the region by the nine to thirteen irregular and broken dark transverse bars on its body, some of which extend onto the dorsal fin. As well, its musculature is firm, not jelly-like as in the Northern Wolffish, and the grinding teeth on the vomer extend to the rear of the mouth behind the rows of palatine teeth (Barsukov *in* Whitehead et al. 1986).

Distribution

Adapted to a broad range of depth and temperature, the Atlantic Wolffish is widely distributed on both sides of the North Atlantic. In the eastern North Atlantic it is found from Iceland, the Faeroes, Spitzbergen, the White Sea, and Murman coast, south to the British Isles and the western coast of France (Wheeler 1969; Whitehead et al. 1986). In the western North Atlantic, it is found off west Greenland and southern Labrador, in the Strait of Belle Isle and the Gulf of St. Lawrence, off the east and west coasts of Newfoundland and on the Grand Banks. Its most southerly range extends from the Scotian Shelf to the Gulf of Maine with occasional strays off New Jersey (Bigelow and Schroeder 1953; Scott and Scott 1988). Thus the Atlantic Wolffish is basically a coldwater fish. Mahon et al. (1998) have identified it as a characteristic member of the "northern, cold, deep, aggregated" demersal fish assemblage that occurs on the continental shelves off northeastern Newfoundland and southern Labrador. The East Coast of North America

*The status report on which this paper is based was reviewed and approved by COSEWIC in November 2000; status assigned – Special Concern.

Strategic Assessment Project (ECNASAP) on-line Groundfish Atlas (http://www-orca.nos. noaa.gov/projects/ecnasap/ecnasap.html) summarizes twenty years of distributional data from scientific research surveys conducted in the western North Atlantic in the map ATLWOL.GIF. The map shows the distribution of Atlantic Wolffish in the western Atlantic is predominately Canadian. Within that area, it is most prevalent and abundant on the deep shelf off northeastern Newfoundland and Labrador.

Protection

Because the Atlantic Wolffish is not at present the target of a directed fishery in the western Atlantic it is unmanaged and there are no specific mechanisms, such as total allowable catch limits, in place that afford it protection. However, the Canadian Atlantic groundfish moratorium imposed in 1992 in response to the collapse of Atlantic Cod, *Gadus morhua*, may have provided some temporary indirect protection for the wolffish by reducing overall trawling pressure. The Atlantic Wolffish was listed (November 2000) as "Special Concern" by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC), but not by The World Conservation Union (IUCN), or the Convention on International Trade in Endangered Species (CITES).

The biology of the Atlantic Wolffish may provide it with some limited protection. As a benthic organism which feeds on the bottom, it is unlikely to be caught in trawls above the ocean floor. Additionally, it frequents caves and crevices between and under large rocks, potentially affording at least some protection from bottom trawls and dredges.

Population Size and Trends

The most important data for assessing the status of Canadian marine fishes under COSEWIC are those which document numerical decline. There is a wealth of such data, which come from regular scientific surveys conducted by government and are expressly designed to monitor changes in abundance of demersal fishes. The same data can also be used to generate secondary but also useful information on possible changes in the number of fish per trawl, the mean size of the fish and the range and habitat.

Data from random-stratified scientific survey trawls off eastern Newfoundland (Atkinson 1994) were provided by Canada's Department of Fisheries and Oceans (DFO) and summarized by Villagarcía (1995; also Haedrich and Barnes 1997). The surveys are intended mainly to assess the size of commercial fish stocks, but they also catch most species in the demersal fish community (Brown et al. 1996). The number of individual trawls made (the number of stations) in any one year can be over a thousand. Subsequently, in July to September 2000, DFO made large amounts of trawl survey data and analyses available from all Canadian areas specifically for our Atlantic Wolffish assessment.

The number/tow (which fishery biologists refer to as the "catch per unit effort" or CPUE) from scientific surveys is used as an index of population size. Over the period from 1978 to 1993, this index was calculated as the total number of Atlantic Wolffish caught off Newfoundland in a year divided by the total number of stations sampled at appropriate depth and temperature ranges for the species in that year. The appropriate depth and temperature ranges for the Atlantic Wolffish are determined using the niche axis approach developed by Fischer and Haedrich (2000) and represent the ranges of those two environmental parameters within which the wolffish is most likely to be encountered; i.e., 100 to 400 m for depth and greater than or equal to -0.5°C for temperature.

The scientific survey data from Newfoundland indicate a sharp decline in the Atlantic Wolffish population. In 1978, the number/tow averaged 10.5 individuals caught in each tow. The following year it dropped more than 25% to 7.1 individuals per tow. It then continued to decline steadily, and by 1993 had fallen to just 0.96 individuals per tow. Over the full period from 1978 through 1993, 16 years or about two wolffish generations, the number/tow declined by 91% (Figure 1). Kulka and DeBlois (1997) note the same general decline for all Newfoundland statistical areas in the period from 1987 to 1995. Since 1995, scientific survey data that include information on Atlantic Wolffish continue to be gathered by DFO. For the Scotian Shelf and Gulf of St. Lawrence, recent catch rates are comparable to ones observed earlier and are low, on average < 1.0 individuals per tow. In the northern Gulf, Atlantic Wolffish are also not very abundant (Powles 2000, personal communication) the average catch rate for 1990–1999 is 0.42 fish per tow. The abundance of Atlantic Wolffish in these more western regions has been low throughout the whole of the past 20 years, and has not shown the decline apparent off Newfoundland where the wolf-fish was once much more abundant than it is today (Figure 1) and where, as the ECNASAP map shows and Mahon et al. (1998) indicate, this species assumes its greatest importance in the Northwest Atlantic.

DFO's main population assessment tool is a Stratified Random Assessment Program (STRAP). This computer analysis takes catches from at least two trawls within defined strata, scales them according to the total area of the stratum (within which the species is assumed to be uniformly abundant), and calculates an estimated number of fish presumed present. To get a total, those numbers are summed across all strata where the fish was encountered. The size of a single stratum can range from 30 to 2817 square nautical miles (average = 697) and, because a single survey trawl sample covers about 0.009

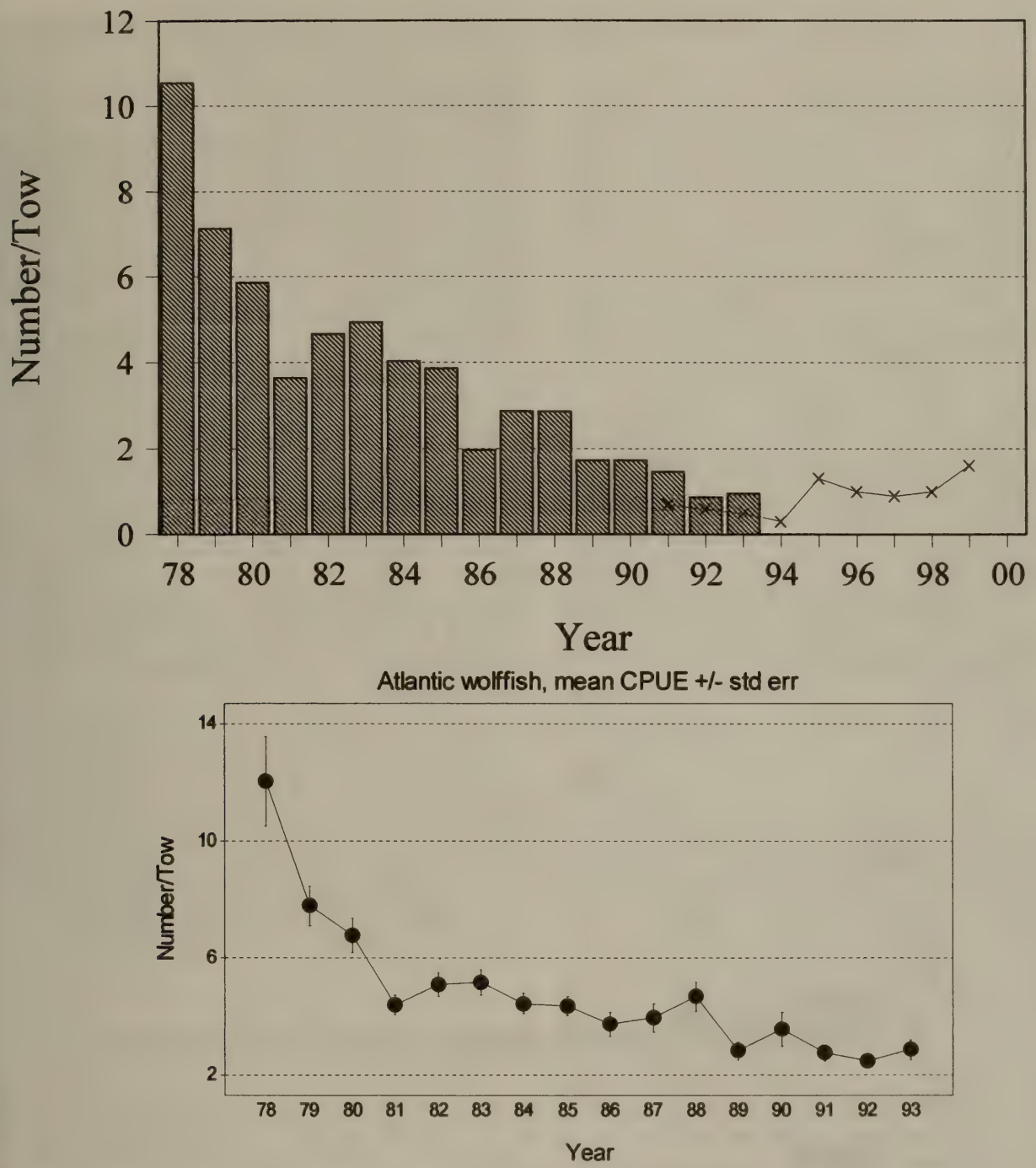

FIGURE 1. Top — Bars: CPUE (no./stn in each year) for Atlantic Wolffish, *Anarhichas lupus*, caught in tows within appropriate depth and temperature ranges, 1978–93; Line, X's — same, all stations (data provided by DFO in September 2000). Bottom — mean CPUE ± standard error for all positive tows. Eastern Newfoundland, 1978–1993, DFO Fall Survey Data.

square nautical miles and there are on average two trawls per stratum, the scale-up is prodigious (Schneider et al. 1999).

The summed estimates from STRAP analysis results for Atlantic Wolffish in all Canadian waters across the period 1978 to 1999 are shown in Figure 2. Because the sampling protocol changed in 1995, values from Newfoundland areas after 1994 are divided by a correction factor for comparability. For demersal species like wolffish, that factor ranges in general from 3.1 for adults to 10.7 for juveniles (Bundy et al. 2000). Calculated for the Atlantic Wolffish alone using Bundy et al.'s (2000) formula, the factor is 4.85. The STRAP results also indicate a large decline in the wolffish population, down 87% over the 16 years from 1978 to 1994 (about two wolffish generations, and with no change in sampling protocol). From 1978 to 1999 (a little less than three wolffish generations 1995–1999 Newfoundland catches adjusted by 4.85), the decline indicated is 83%. Despite the debatable value of STRAP's absolute numbers, the annual estimates

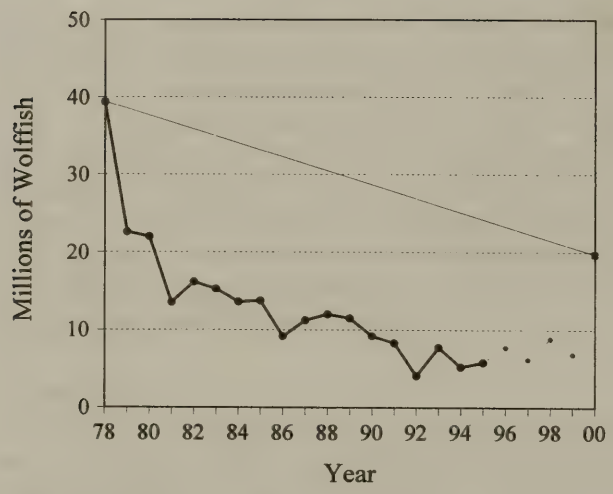

FIGURE 2. Twenty years of STRAP analyses for Atlantic Wolffish, Canadian waters. Solid line, filled circles: Engels trawl estimates. From 1978 to 1994 (16 years; i.e., about two wolffish generations) there was no change in sampling method, and the decline is 87%. Dotted line, small dots: corrected estimates from Campelen trawls using the factor 4.85 (see text), 1995–1999. Based on information provided by DFO in September 2000. Straight line shows the COSEWIC endangered criterion.

turn out to be well-correlated (r = 0.93) with the simple metric we prefer, the number/tow.

From 1978 tto 1993, the relative frequency of high survey catch rates off Newfoundland has declined, and low catch rates have been on the rise (Figure 3). In 1978, catches of five or less wolffish in a tow constituted less than 40% of all catches; by 1984 the frequency of low catches (≤5) had risen to more than 70%, and in 1993 it was almost 90%. The increased frequency of low catch rates is another indication of declining population density.

The trend to a declining mean size of fish, considered together with the declining numbers, is yet another indication that wolffish populations are in trouble. These trends vary according to area, but all are down. The average size of Atlantic Wolffish from the Scotian Shelf and southern Gulf of St. Lawrence, while showing inter-annual variation, declined overall by 50% or more from the mid-1980s to the present; the trend lines are essentially the same. Off Newfoundland, mean wolffish size declined from around a kilo in 1978 to near 700 gm in 1993. Fish of that size are probably not yet

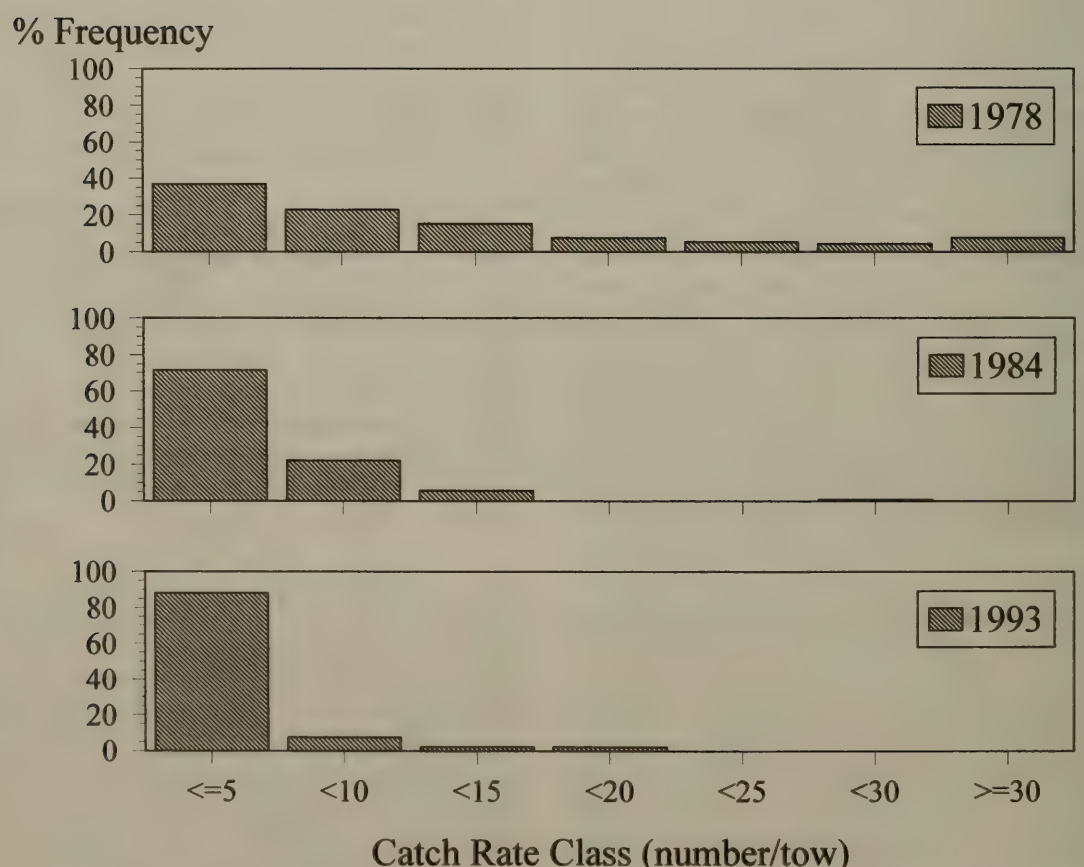

FIGURE 3. Percent frequency of large and small catches of Atlantic Wolffish, *Anarhichas lupus*, by catch rate classes of 5, off eastern Newfoundland, 1978–1993. DFO Newfoundland Fall Survey Data.

mature. In the Northern Gulf, the average size in the period 1990–1999 is less than 500 gm.

To the north in Greenland waters, scientific trawl surveys (Rätz 1997; Möller and Rätz 1999) have been done differently than in the U.S. and Canada, so CPUEs are not directly comparable. Biomass and abundance of Atlantic Wolffish off East Greenland increased somewhat from 1982 to 1998, but off West Greenland (the region nearest to Canada), biomass has declined by about an order of magnitude and numbers are down by about half. Mean age in the whole Greenland population in 1998 (= 4 yr) is half of what it was in 1982 (Möller and Rätz 1999), so the picture appears to be quite similar to that seen off Newfoundland. To the south, Atlantic Wolffish have never been very abundant in U.S. waters (CPUE <0.2 individuals per tow). There, wolffish did experience a significant decline in the mid-1970s, several years before one of much greater magnitude in Atlantic Canada.

The period since 1992 is an anomalous one for all Canadian waters. Relative to the past, fish populations are at an all-time low. For that reason, bans on fishing (moratoriums) have been in effect in most regions for various periods of time, and these continue. Fishing predation is thus much relaxed, and populations should do better as long as that situation continues, which will not be forever. A cornerstone in the Fisheries Resource Conservation Council's (FRCC) approach to management (this quasi-independent group advises the Minister on the status of commercial fish stocks) is adherence to the precautionary principle "when in doubt, err on the side of the fish" (FRCC 1996).

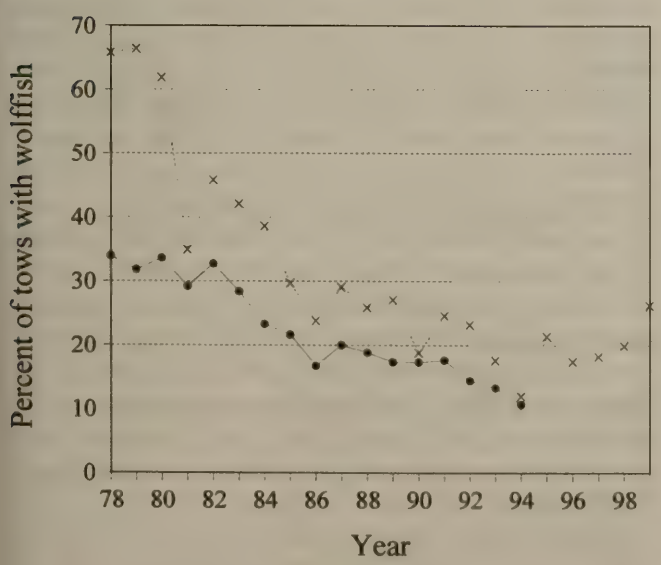

FIGURE 4. Percentage of scientific survey stations that captured Atlantic Wolffish, *Anarhichas lupus*, 1978–1999. Solid line, circles: Canadian waters, ECNASAP data. Dotted line, Xs: Newfoundland waters only, data provided by DFO in September 2000. Note: sampling protocol changed in 1995.

General Biology

Habitat

The Atlantic Wolffish is found principally in the deep waters of the continental shelf on rocky or hard clay bottoms, and only occasionally on sand or mud. Like other wolffish species, its migrations are local and limited (Templeman 1984) and it does not form large schools. It is, however, known to perform small seasonal inshore-offshore migrations (Keats et al. 1985). It is found anywhere from very shallow water to 500 m deep and is said to prefer depths between 100 and 150 m; this apparent preference, however, varies depending on the locality. The Atlantic Wolffish is a cool to cold water fish, tolerating a broad temperature range of -1°C to 10°C, though preferring temperatures between -0.4°C and 6°C. These preferred temperature ranges vary with locality.

The percentage of all annual DFO survey stations where the Atlantic Wolffish was actually caught declined steadily from near 35% in 1978 to about 10% in 1994 (Figure 4). For the area off Newfoundland, the Atlantic Wolffish occurred in 88% of the stations where it was expected (according to preferred depth and temperature ranges) in 1978, and that level of occurrence continued until about 1985. After 1985, the percentage declined steadily to only 33% in 1993.

Reproduction

Spawning in the Atlantic Wolffish varies in time and place. Off the east coast of Newfoundland some Atlantic Wolffish migrate to shallow inshore waters in spring, spawning in September with hatching occurring by mid-December (Keats et al. 1985). In both the Gulf of Maine (Nelson and Ross 1992) and eastern Newfoundland (Keats et al. 1986), it is thought that only fish over 50 cm and sexually mature move inshore, while smaller, juvenile fish remain in deep water. In Greenland the maximum number of spawners were observed by Beese and Kandler (1969) in September and October. In Iceland the situation is quite different from that in Newfoundland; Jónsson (1982) reports that the Atlantic Wolffish moves from shallow into deeper waters to spawn from September to December or January, subsequently returning to shallow waters to feed. Similarly, spawning and feeding are exclusive events in the White Sea, with spawning occurring in the deep waters between 70 m and 300 m from August through September (Pavlov and Novikov 1993). Keats et al. (1985: 2567) point out that the literature "suggests geographical and depth-related variability in the reproductive season of Atlantic Wolffish". As such, discrete geographical populations of Atlantic Wolffish may have distinct and different life histories, a possibility that requires further study.

Wolffish lay some of the largest eggs of any fish known — up to 6.0 mm in diameter. The eggs are deposited in a large mass on the bottom and are

guarded by the male. Larvae remain mostly close to the bottom, rarely swimming to the surface and tending to remain close to the site of hatching.

Limited adult migrations and the restricted dispersal of larvae from their hatching site are potential risk factors for the survival of Atlantic Wolffish populations on the smaller scale. If the population of a given region is decimated through environmental or anthropogenic causes, it is unlikely to be replenished by populations from elsewhere. The broad range of temperature and depth to which the Atlantic Wolffish appears to be adapted may be indicative of the unique depth and temperature regimes of discrete and separate, rather than confluent, populations.

Growth

Growth rates of the Atlantic Wolffish in Canadian Atlantic waters are unknown and there are little data available for other areas. In Europe, it takes a fish three years to reach 25 cm TL (Wheeler 1969), and Scott and Scott (1988) report that growth rates in Atlantic Canada are slow after the first summer. Growth slows even further at five to six years of age when energy is diverted to gonadal development (Nelson and Ross 1992). Off eastern Newfoundland the Atlantic Wolffish reaches maturity between 43 and 67 cm TL (weights of 0.56 and 2.39 kg); fifty percent of individuals between 52 and 60 cm TL (1.02 and 1.57 kg) are mature (Templeman 1986). Fish of this size are 8 to 10 years old. Atlantic Wolffish are known to reach 152 cm in length and specimens aged to twenty years have been taken off Iceland (Scott and Scott 1988).

Feeding

The Atlantic Wolffish feeds primarily on hard-shelled benthic invertebrates such as echinoderms, molluscs, and crustaceans. It is thought to be a key player in the ecosystem, known to control the density and spatial distribution of species such as Green Sea Urchins, *Strongylocentrotus droebachiensis* (Hagen and Mann 1992), crabs (Witman and Sebens 1992) and Giant Scallops, *Placopecten magellanicus* (Stokesbury and Himmelmann 1995). The Atlantic Wolffish also consumes small amounts of fish, particularly Redfish, *Sebastes* sp. Young wolffish eat echinoderms almost exclusively but this food source becomes less important as the fish grows. While mature males reduce feeding close to spawning time and until their egg-guarding duties have ceased, females reduce feeding as gonads mature, but resume feeding immediately following spawning (Keats et al. 1985). Little is known about what preys on the Atlantic Wolffish, but juvenile specimens have been reported in the stomach contents of cod (Scott and Scott 1988).

Limiting Factors

There are no direct studies of factors responsible for the declines observed in wolffish abundance. Following the Northern Cod collapse off Newfoundland in 1992, a number of causes for the cod decline were suggested, including especially environmental changes. On a community level, similar declines in both commercial and non-commercial fish species there seemed difficult to understand without invoking such causes (Gomes et al. 1995). The consensus now is that environment may have played some role, but overfishing was clearly the major cause of the declines observed in most groundfish species (Sinclair and Murawski 1997; Villagarcía et al. 1999). When assessed over only a slightly longer time scale, fishing in the area is argued to have been responsible for the extraordinary decline of the large and once abundant and widely-distributed Barndoor Skate, *Raja laevis* (Casey and Myers 1998).

The Atlantic Wolffish has been landed from commercial fisheries for many years. Once a directed target of the western Greenland fishery, it is now taken incidentally as by-catch only. There, Möller and Rätz (1999) report that calculated wolffish mortality is positively correlated with commercial landings of cod and shrimp. This indicates that fishing for other species can have a negative impact on wolffish through removal in the by-catch. There is no directed fishery for the Atlantic Wolffish in Canadian waters, though it is taken as by-catch by offshore trawlers. Recently, wolffish filets have begun to appear in St. John's fish shops, and there is concern that with developing markets "fishermen might target wolffish as a 'directed by-catch'"(FRCC 2002: 46).

In fisheries data compiled by the Food and Agriculture Organization of the United Nations (FAO), wolffish landings for the western North Atlantic are reported for the whole family (three species) rather than for each individual species; the Atlantic Wolffish comprises the majority of those landings in Canada (Kulka and DeBlois 1997). While the northeastern Atlantic fishery (apparently focussed more on the Spotted Wolffish, *A. minor;* Wheeler 1969) has had annual landings of around 30 000 tonnes since the late 1950s, with two peaks of over 50 000 tonnes in 1962 and 1974, the northwestern Atlantic fishery has always been smaller. Northwest Atlantic landings (Figure 5) hovered around 5000 tonnes through the 1950s and then rose through the 1960s and 1970s to a peak of 22 000 tonnes in 1979. Landings then declined steadily through the 1980s and 1990s; in 1984 they stood at 6000 tonnes and by 1996 had fallen to 1700 tonnes.

The principal countries involved throughout in the history of the wolffish fishery have been Canada and Greenland, each with about a third of the landings from 1950 through 1996. The Soviet Union and East Germany also played significant roles in this fishery through the 1960s and 1970s, with East Germany responsible for almost 70% of 1979's record catch.

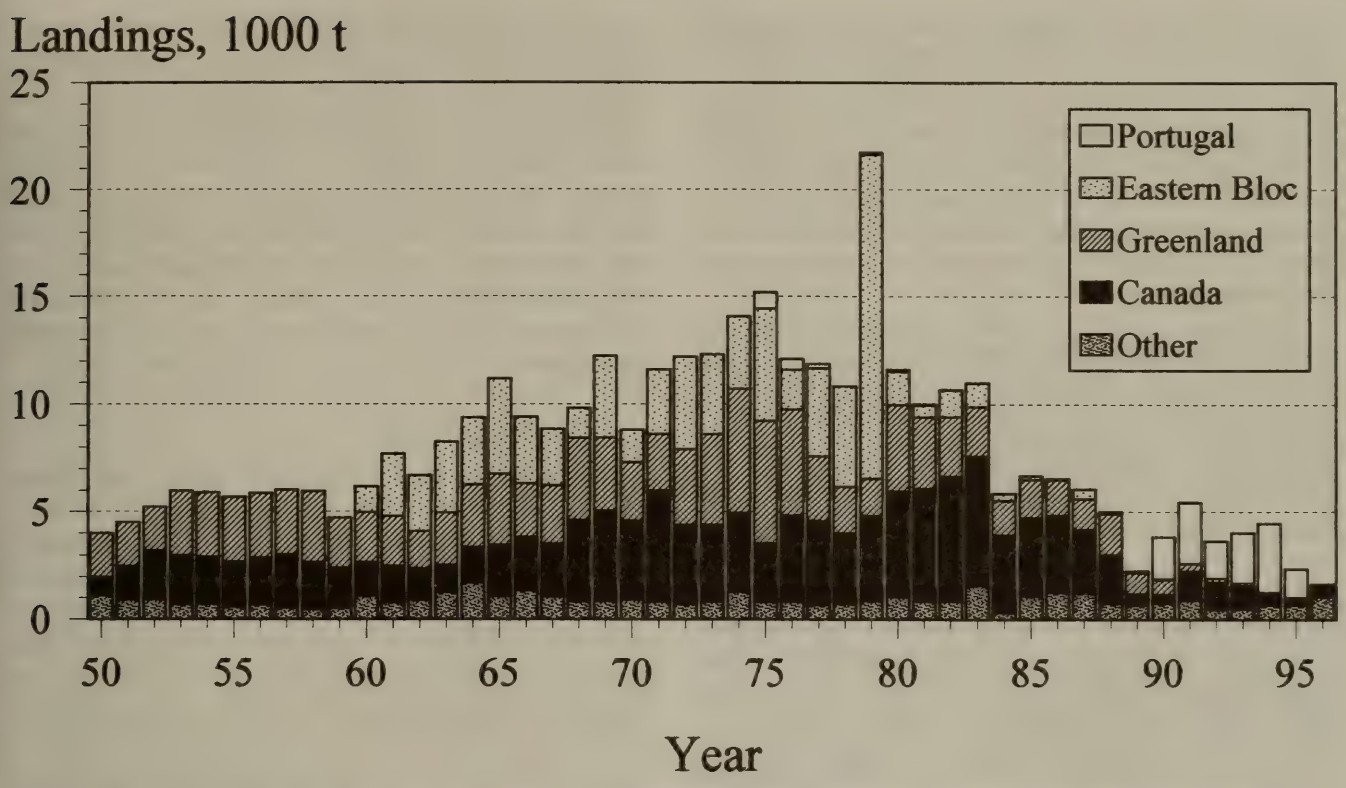

FIGURE 5. History of the northwest Atlantic fishery for Atlantic Wolffish, *Anarhichas lupus*, 1950–1996. FAO Data.

The Soviet Union and East Germany were essentially out of the picture by the early 1980s, and by 1990 Greenland had seriously curtailed its fishing efforts as well. In recent years, from 1990 through 1996, Portugal has become the major participant in a much reduced fishery.

Apart from the direct adverse impact of fisheries on Atlantic Wolffish, human activities also have indirect and detrimental effects on this species. The groundfish trawls, generally otter trawls, in which wolffish are caught can result in incidental mortality and damage to fish which come in contact with the mobile fishing gear but are not caught. Perhaps even more importantly, the steel doors or otterboards of the net, along with heavy bottom lines and rollers, scour the seabed as they are dragged across it (Watling and Norse 1998). This practice may cause significant habitat damage by removing or re-distributing the rocks and boulders under which these fish shelter, spawn and build nests. Studies on Georges Bank (Collie et al. 1997) and in the Gulf of Maine (Auster et al. 1996), areas within the southern limit of the Atlantic Wolffish's range, show the considerable degree of damage that can result from bottom dragging there. Jennings and Kaiser (1998) provide an excellent overview of the entire question of fishing impacts on habitat; they point out that these can vary quite a bit depending on local conditions, but suggest that the greatest and most lasting impacts are most likely to occur on hard substrates in deep water; i.e., just those habitats favoured by the Atlantic Wolffish.

Bottom trawling for fish and dredging for scallops and clams, in addition to digging up and disrupting bottom habitats, also re-suspends bottom sediments, which can smother spawning areas and damage gills. Re-suspension of sediments may change the sediment chemistry or release settled toxic heavy metals. Other human activities such as channel dredging and aggregate extraction may do considerable harm to bottom habitats by destabilizing the seabed, increasing erosion, and polluting previously healthy areas (Messieh et al. 1991).

Status Determination

Under IUCN Categories and Criteria, criterion A: "Declining Population", the Atlantic Wolffish, with its 87% decline rate over a bit more than two generations, would fall in the category Critically Endangered, defined as a "population decline rate at least 80% in 10 years or three generations" (Hilton-Taylor 2000: 55).

Musick (1999) feels that marine fish, by virtue of their widespread distribution and thus relatively great abundance, should be treated differently from other species in respect to consideration as species at risk. He proposes an approach that involves two steps, first determining the productivity class of a species (based on growth, fecundity and age characteristics) and then classifying it on the basis of arbitrary decline thresholds. The Atlantic Wolffish, on the basis of age at maturity and lifespan, falls in Musick's (1999) "Low" productivity category, and exhibits a decline of 87% over less than three generations, just over the 85% decline threshold for

species in the Low category. According to Musick's proposed scheme, the Atlantic Wolffish would be listed as Vulnerable and would then be subjected to closer scrutiny for final classification. That scrutiny would explicitly consider issues concerning the possibility of a shrinking range, local distribution, nesting habit, and possibility of habitat destruction. The data available on all these issues arguably support upgrading.

Hutchings (2000) shows that exemption of marine fish from established species-at-risk criteria cannot be supported on the basis of empirical data and, furthermore, to do so would be inconsistent with a precautionary approach to fisheries management and the conservation of biodiversity. He further argues that extinction risk alone is not very useful from either a management or an ecological perspective and that the other face of the issue, the probability of recovery, should be weighed seriously in assigning status. He suggests a classification scheme that would replace Vulnerable to Critically Endangered with Conservation Categories ranging from Priority I to IV. The empirical data show that population recovery in marine fish is negatively correlated to the magnitude of population decline. With its high decline rate of 87%, the likelihood that Atlantic Wolffish populations would show signs of recovery after 15 years is very low, and this species would fall in Hutching's Conservation Category Priority IV, his highest rating.

The FRCC and the North Atlantic Fishery Organisation (NAFO) have found Atlantic Wolffish populations to be in poor shape. In the far north of Canadian Atlantic waters (subarea 1), NAFO (2000) notes that Atlantic Wolffish remains severely depleted and recommends that there be no fishery for the species in 2001 and 2002. FRCC (2000) indicate that for Atlantic Wolffish on the Scotian Shelf the stock is low, the biomass is declining, growth and condition are below average and the age structure is poor. They recommend that there be no fishery for the next two years and that restrictive measures be put in place to minimize by-catch, noting that "concentrated fishing effort . . . has likely contributed to overall decline" (FRCC 2000: 42).

The DFO scientific survey data show an 87% decline in the number of Atlantic Wolffish in Canadian waters over the 16-year period (about two wolffish generations) from 1978 to 1994. Under criterion A: "Declining Population" of COSEWIC's Risk Categories and Criteria, this population decline rate places the Atlantic Wolffish clearly in the category Endangered, defined as a "population decline rate at least 50% in 10 yrs or 3 generations" (Haedrich, 2001: appendix page 2).

At its annual meeting in November 2000, COSEWIC considered the Atlantic Wolffish, and after an extended debate voted to list it as Special Concern. The statement accompanying that designation read: "The total population of this large, solitary, slow-growing, late-maturing, nest-building benthic fish has declined significantly since the 1970's. Apparent threats are related to fishing and habitat alteration, perhaps compounded by environmental change. Met criterion for Endangered A1b, but because it is not considered to be facing imminent extinction, it was listed as Special Concern on the grounds that it is a species that would likely become at risk if not for active protection and management."

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The Muskellunge, *Esox masquinongy*, as a host for the Silver Lamprey, *Ichthyomyzon unicuspis*, in the Ottawa River, Ontario/Québec

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A new host, *Esox masquinongy,* the Muskellunge, for the Silver Lamprey, *Ichthyomyzon unicuspis,* is reported. Fifteen Silver Lamprey/Muskellunge interactions were documented in a 90-km section of the lower Ottawa River, on the Ontario as well as the Québec side, from Ottawa to Hawkesbury between 1992 and 2001. Sites of attachment were predominantly on the back. Number of marks per host varied between 1 and 31 with a mean of 10.6. There was evidence of cytolytic activity of the buccal gland secretions. Shallowness of the fresh wounds indicated blood feeding rather than flesh feeding. Survival of the host was indicated by the presence of healed wounds in 26.7% of the cases. Muskellunge over 122 cm in total length were preferred over smaller individuals. Lampreys appeared to be more highly concentrated in the 50-km stretch of the lower Ottawa River, between Thurso and Hawkesbury, than they were in the 40-km stretch upstream, between Ottawa and Thurso.

Cet article fait mention d'un nouvel hôte pour la Lamproie Argentée, *Ichthyomyzon unicuspis.* Il s'agit du Masquinongé, *Esox masquinongy.* Quinze interactions entre la Lamproie Argentée et le Masquinongé furent rapportées dans une section de 90 km de la rivière des Outaouais, du côté de l'Ontario aussi bien que celui du Québec, entre Ottawa et Hawkesbury pour la période 1992 à 2001. Les points de fixation étaient surtout sur le dos. Le nombre de marques variait entre 1 et 31 par hôte avec moyenne 10,6. Une action cytolytique des sécrétions des glandes buccales était indiquée. Les plaies non cicatrisées étant peu profondes, une diète de sang plutôt que de chair était indiquée. La survie de l'hôte était indiquée par la présence de plaies cicatrisées dans 26,7% des cas. Les Masquinongés de taille supérieure à 122 cm de longueur totale étaient choisit de préférence aux individus de taille moindre. Les lamproies semblaient être plus concentrées dans une section de 50 km de la rivière des Outaouais entre Thurso et Hawkesbury qu'elles ne l'étaient dans la section de 40 km en amont, entre Ottawa et Thurso.

Key Words: Silver Lamprey, *Ichthyomyzon unicuspis,* Petromyzontidae, parasite, Muskellunge, *Esox masquinongy,* Esocidae, host, Ottawa River, Ontario, Québec.

Adult Silver Lampreys, *Ichthyomyzon unicuspis,* feed ectoparasitically on the blood of a wide variety of freshwater fish species. A survey of the literature indicated that 19 freshwater fish species serve as hosts to the Silver Lamprey in nature, for feeding and/or transport (Table 1). An additional five fish species that have served as hosts under laboratory conditions (Roy 1973) are omitted rom Table 1. A record of Rainbow Trout, *Oncorhynchus mykiss,* acting as a host was dismissed because it was based on unconfirmed evidence, the lamprey not having been kept for identification (Hubbs and Trautman 1937). Finally, a number of other fish hosts were reported by Forbes and Richardson (1920), Starrett et al. (1960), and Hubley (1961) for Silver Lamprey and Chestnut Lamprey, and by Cochran and Marks (1995), for Silver Lamprey and Sea Lamprey; however, it could not be established with certainty which species in the pair was responsible for the marks, and therefore, these were also omitted from Table 1.

This paper presents data on a new host species, the Muskellunge, *Esox masquinongy,* based on 15 host/parasite interactions with Silver Lamprey. The Ottawa Valley Chapter of Muskies Canada has kept archives, including photographs, of lamprey-induced marks on Muskellunge from the Ottawa River since 1992 and provided these to the author. The Silver Lamprey was assumed to be the only species responsible for the marks because it was the only one identified in the seven cases in which attached lampreys were retrieved. Additionally, the only other parasitic lamprey recorded from the Ottawa River basin, the Chestnut Lamprey, *Ichthyomyzon castaneus,* is rare in Ontario and Québec compared to the Silver Lamprey (Renaud et al. 1996; Renaud and de Ville 2000), and therefore, is unlikely to have contributed significantly to the marks on Muskellunge reported here.

Material and Methods

The 15 Muskellunge in this study (Table 2) were caught by angling in the Ottawa River (Figure 1) by members of the Ottawa Valley Chapter of Muskies Canada. They were released alive after measurement of total length (TL, nearest cm), fork length (FL), and number, position (i.e., dorsal, lateral, ventral) and condition (i.e., fresh, bleeding wound or scarred, healed wound) of lamprey-induced mark(s). A

Table 1. Natural fish hosts of the Silver Lamprey, Ichthyomyzon unicuspis. Scientific and common names follow Robins et al. (1991).

Fish Host	Common Name	Source
Acipenser fulvescens	Lake Sturgeon	Vladykov (1949, 1985), Roy (1973), Becker (1983), Choudhury and Dick (1993)
Acipenser oxyrhynchus	Atlantic Sturgeon	Vladykov (1949), Roy (1973)
Polyodon spathula	Paddlefish	Wagner (1904, 1909), Hubbs and Trautman (1937), Becker (1983), Lyons (1993), Runstrom et al. (2001)
Lepisosteus osseus	Longnose Gar	Bensley (1915), this study
Carassius auratus	Goldfish	George (1985)
Cyprinus carpio	Common Carp	Becker (1983)
Catostomus catostomus	Longnose Sucker	Allin (1951), Roy (1973)
Catostomus commersoni	White Sucker	Hubbs and Trautman (1937), Allin (1951), Roy (1973)
Ictiobus niger	Black Buffalo	Hubbs and Trautman (1937)
Ameiurus nebulosus	Brown Bullhead	Hubbs and Trautman (1937), George (1985)
Esox lucius	Northern Pike	Bensley (1915), Hubbs and Trautman (1937), Becker (1983)
Esox masquinongy	Muskellunge	this study
Coregonus clupeaformis	Lake Whitefish	Hubbs and Trautman (1937)
Salvelinus fontinalis	Brook Trout	Roy (1973)
Salvelinus namaycush	Lake Trout	Hubbs and Trautman (1937)
Morone chrysops	White Bass	Becker (1983)
Morone saxatilis	Striped Bass	Roy (1973)
Ambloplites rupestris	Rock Bass	Hubbs and Trautman (1937)
Micropterus dolomieu	Smallmouth Bass	Hubley (1961)
Stizostedion vitreum	Walleye	Hubbs and Trautman (1937)

photograph of the host was taken and any attached lamprey removed and retained. In one instance, however, the Muskellunge did not survive, despite attempts to release it alive, and it was retained along with the attached lamprey. The seven lamprey specimens and the one Muskellunge were given Canadian Museum of Nature Fish Collection (CMNFI) catalog numbers (Table 2). Total length (TL) and disc length (d) of the freshly-preserved lampreys were measured to the nearest 0.5 mm.

Results

The seven lampreys retrieved from the Muskellunge were identified as *Ichthyomyzon unicuspis* based on their possession of a single dorsal fin and only unicuspid endolaterals. They measured 105.0–232.0 mm TL (mean = 150.6 and standard deviation (SD) 46.6). Their oral disc lengths measured 10.5–22.0 mm (mean = 14.9 and SD 4.1). The single Muskellunge kept (record number 12, Table 2) was identified using Scott and Crossman (1973). It was the only host available to the author as a specimen, instead of a photograph, and was therefore thoroughly examined for lamprey-induced marks. It had five fresh wounds on the dorsal surface; two immediately behind the head, one at about a third of the way down the body and two near the origin of the dorsal fin. It had one fresh wound on the right opercle and nine on the right lateral surface of the body (five fresh and four healed). It had one fresh and three healed wounds on the left opercle; the fresh one was subcircular and measured 21 mm along its longest axis. One fresh wound was present on the left branchiostegal membrane and two fresh wounds were on the left lateral surface of the body near the head. On the ventral surface it had four healed wounds: three under the right pectoral fin and one between the right pelvic and anal fin. Additionally, at capture, one feeding adult lamprey was inside the branchial cavity of the host.

Fourteen Muskellunge hosts measured 94–135 cm TL (mean = 122.6 and SD 12.0; the 104 cm FL Muskellunge was not included because its measurement was not comparable with the others). Three of the hosts (record numbers 8, 11, and 12, Table 2) weighed 18, 19, and 13 kg, respectively. The number of marks per host (n = 15) varied between 1-31 (mean = 10.6 and SD 10.5). Twelve of the 15 Muskellunge (80%) had multiple marks and two of these hosts had two attached lampreys (record numbers 4 and 11, Table 2) at the time of capture (Figure 2). The mean number of attached lampreys on 10 hosts was 1.2. The condition of the marks (i.e., fresh or scarred) was recorded for all 15 hosts. All had fresh wounds and four of them (26.7%) also had scarred wounds. The lamprey-induced wounds, whether fresh or scarred, were more or less circular in shape and corresponded to the oral disc size. Fresh wounds were shallow, of reddish color, and the integument over the entire surface, at the site of fresh wounds, was missing (Figure 2). The position of the lamprey-induced marks was recorded in 13 of 15

TABLE 2. Collection data for the 15 Muskellunge – Silver Lamprey interactions in the Ottawa River.

Record Number	Date of Collection	Locality with Geographical Coordinates	Water Depth, m	Muskellunge TL, cm	Number of Lamprey Marks, Condition and Position	Lamprey TL, mm	Lamprey d, mm	Catalog Number
1	28 October 1992	Ontario, off de Cheval Island, near South Nation River, 45°34'30"N 75°10'30"W	4.5	122	11 fresh on dorsal and lateral surfaces	NA	NA	NA
2	October 1993	Québec, just west of Petite Blanche River, 45°30'0"N 75°33'30"W x	3	117	6 fresh on dorsal surface	NA	NA	NA
3	August 1996	Québec, at confluence with Kinonge River, 45°39'N 74°55'W	1.8	128	16 fresh on dorsal surface	NA	NA	NA
4	October 1997	Ontario, offshore of L'Orignal Bay, across from Rouge River, 45°37'N 74°44'W	3.5	127	31 fresh on dorsal surface	NA	NA	NA
5	22 June 1999	Québec, west of Montebello, 45°36'N 75°0'W	NA	102	1 fresh on dorsal surface	107.5	11.5	CMNFI 1999-38
6	July 1999	Québec, Montebello, 45°39'N 74°56'W	3	124	5 fresh on lateral surface	NA	NA	NA
7	13 July 1999	Québec, west of Montebello, 45°36'N 75°0'W	NA	135	1 fresh on dorsal surface	158.5	18.0	CMNFI 2001-3
8	12 September 1999	Ontario/Québec, between Rockland and Wendover, 45°35'N 75°12'W	1	133	30 fresh mostly on dorsal with fewer on lateral surfaces	232.0	22.0	CMNFI 2001-6
9	30 October 1999	Ontario, Rockliffe Park, in front of lookout, east of Governor Bay, Ottawa, 45°27'N 75°41'W	6	104 (Fork Length)	1 fresh and 2 healed on lateral surface	187.5	15.5	CMNFI 2001-7
10	21 June 2000	Québec, mouth of Lièvre River, 45°31'N 75°26'W	NA	94	1 fresh, position not recorded	119.0	12.0	CMNFI 2001-12
11	21 June 2000	Québec, mouth of Gatineau River, 200 m east of MacDonald-Cartier bridge, 45°27'N 75°42'W	NA	132	1 fresh on ventral and 6–7 fresh and healed on dorsal surface	105.0	10.5	CMNFI 2001-13
12	15 July 2000	Ontario/Québec, near Hawkesbury, 45°37'N 74°37'W	4	131	15 fresh and 11 healed on dorsal, lateral and ventral surfaces	145.0	15.0	CMNFI 2001-14
13	15 July 2000	Ontario/Québec, near L'Orignal, 45°37'N 74°41'W	5	117	6-8 fresh, position not recorded	NA	NA	NA
14	23 September 2000	Québec, about 300 m east of Kinonge River, 45°38'55"N 74°54'30"W	2.5	133	12-15 fresh and healed on dorsal and lateral surfaces	NA	NA	NA
15	6 July 2001	Québec, mouth of Lièvre River, 45°31'N 75°26'W	NA	122	3 fresh on dorsal surface	NA	NA	NA

FIGURE 1. Co-occurrences of Muskellunge and Silver Lamprey in the Ottawa River, Ontario/Québec, 1992-2001 (solid circles). The numbers without parentheses refer to the records listed in Table 2 and those in parentheses to the number of lamprey-induced marks on a Muskellunge. The locations of major centres are marked by solid triangles.

hosts; 84.6% of these had marks on their dorsal surface, 46.2% on the lateral surface and 15.4% on the ventral surface. Six hosts had marks only on the dorsal surface; two only on the lateral surface; and none only on the ventral surface. Three hosts had marks on both the dorsal and lateral surfaces; one had marks on both the dorsal and ventral surfaces and one had marks on all three surfaces. Muskellunge with fresh wounds were collected between 21 June and 30 October. The Muskellunge were collected at water depths between 1 and 6 m (mean = 3.4 and SD 1.5). During 2000, along the length of the Ottawa River which comprised the study area (Figure 1), Muskellunge less than 91 cm TL bore no marks, individuals between 91 and 122 cm TL showed a 2-5% incidence of marks and ones greater than 122 cm TL showed a 21.4% (i.e., 6 out of 28) incidence of marks (Hedrik Wachelka, personal communication). The sample sizes for the first two categories were not reported.

Discussion

The adult feeding lampreys in this study were well within the range of total lengths, 85 – 392 mm, reported for adults of the species (Lanteigne 1981; Cochran and Marks 1995). Few studies have examined the parasite-host interactions in the Silver Lamprey. Vladykov and Roy (1948) mentioned that transformed specimens of Silver Lamprey were collected on 11 species of freshwater fishes in Québec, but did not list them. George (1985) reported that the majority of about 430 dead or moribund Goldfish, *Carassius auratus*, all approximately 25 cm TL in a 3-km section of the Hudson River, New York State, exhibited surface or penetrative, slightly hemorrhagic, wounds varying between 9 and 50 mm in size, and that these were attributable to Silver Lamprey. George (1985) added that the 9-mm wounds corresponded well to the disc length of the Silver Lamprey collected off the Goldfish. However, the 50-mm wounds are suggested to be caused by the Sea Lamprey, *Petromyzon marinus*, which also occurs in the Hudson River (Smith 1985). In the largest specimens of Silver Lamprey available to them, 301-330 mm TL, which were presumed to have the largest discs, Hubbs and Trautman (1937)

FIGURE 2. Muskellunge (record number 4, Table 2) with two attached feeding lampreys (visible at lower right) and 31 fresh lamprey-induced marks (about 20 visible) on its dorsal surface.

reported a mean disc length of 7.2% of TL. If we take the maximum value in that size class range, 330 mm, this translates into a disc length of 24 mm which is slightly larger than the largest disc measured in this study, 22.0 mm, but considerably less than 50 mm. Vladykov and Kott (1980) recorded a disc length of 52 mm on a 680 mm TL Sea Lamprey. Those 50-mm wounds were therefore likely caused by Sea Lamprey.

The Muskellunge is an ideal host for the Silver Lamprey because of its rather small cycloid scales and the fact that as an ambush predator it lies motionless in heavily vegetated slow-moving waters waiting for prey to come within striking range. The low incidence of marks on the ventral surface of Muskellunge (15.4%) relative to the percentages which occurred on the lateral (46.2%) and dorsal (84.6%) surfaces supported the idea that while the Muskellunge lies motionless waiting for its prey, its underside was generally less available for attachment by the lamprey. The relative surface area of the three body regions of the host would not explain the difference in percentage incidence of marks observed because the lateral region is at least twice (two sides) as large as either the dorsal or ventral region. This was in marked contrast with the situation reported by Wagner (1909) in Paddlefish, *Polyodon spathula*, where, although marks may be found on all surfaces of the fish, the attachment of Silver Lamprey was predominantly on the ventral surface. This difference in preferred site of attachment is believed to be attributable to differences in the life habits of the hosts. Unlike Muskellunge, Paddefish are pelagic fishes that are constantly moving in the water column feeding on plankton (Wagner 1909), and therefore, their underside is constantly available for attachment by lampreys. This indicates that Silver Lamprey are flexible in their site of attachment. Cochran (1986) suggested that dorsal attachments of the Chestnut Lamprey, *Ichthyomyzon castaneus*, to hosts in shallow watercourses with relatively rough substrates were an adaptation to prevent the lamprey's detachment or injury through abrasion against the substrate. Similarly, protection would have been afforded the Silver Lamprey found inside the branchial cavity of one of the hosts in this study (record number 12, Table 2). Wagner (1904) reported at least one case in which a lamprey had found its way under the opercular flaps of Paddlefish.

Because the integument was missing over the entire surface of the fresh wounds on the Muskellunge (Figure 2) rather than being limited to the central area of the wound where the rasping action of the transverse lingual lamina occurs, I suggest that the buccal gland secretions in *Ichthyomyzon unicuspis* have a cytolytic action similar to that in

Petromyzon marinus (Lennon 1954). The shallowness of wounds on the Muskellunge was an indirect indication that the Silver Lamprey was a blood feeder rather than a flesh feeder. Blood feeding in this species had been inferred by Potter and Hilliard (1987), based on its dentitionalcharacteristics, as well as its relatively large oral disc and buccal glands, being similar to that of a known blood-feeder, *Petromyzon marinus*. Additionally, the presence of healed injuries in 26.7% of the hosts in this study was indicative of non-lethal past events of parasitism. Lyons (1993) stated that most of the 240 Paddlefish he examined had healed wounds and that this indicated survival from lamprey attacks.

No deep wounds were found on the Muskellunge in this study. The penetrative wounds on Goldfish reported by George (1985) may well have been caused by Sea Lamprey rather than Silver Lamprey (see above). Penetrative Sea Lamprey wounds reaching the coelomic cavity as well as perforating cranial bones were observed in both the lab and thefield by Lennon (1954). In the lab situation, Silver Lamprey are certainly capable of penetrative wounds into the coelomic cavity and perforating cranial bones (Roy 1973), but whether this happens in nature is not known. Such severe wounding would almost certainly result in the relatively quick death of the host and is unlikely to be observed in nature unless large-scale sampling is conducted.

The presence of fresh wounds on Muskellunge caught between 21 June and 30 October indicated that Silver Lamprey were actively feeding during that period. Authors usually do not specify whether lamprey attachments on hosts were for the purposes of feeding or transport. In the case reported here, it was quite clear from the wounds inflicted on the Muskellunge that feeding was involved. Likewise, feeding occurred in the case of *Polyodon spathula* (Lyons 1993) and *Carassius auratus* (George 1985). Although the maximum number of 28 fresh wounds in *P. spathula* reported by Lyons (1993) was similar to the 31 reported here for Muskellunge, the mean number of 6.1 fresh marks (Lyons 1993) was substantially lower than the 9.8 (n = 13) reported here.

The incidence of lamprey-induced marks in this study, 21.4% in Muskellunge larger than 122 cm TL, was significantly lower than that reported by Wagner (1909) for Paddlefish. Virtually all of the 1500 he examined from Lake Pepin, Wisconsin, had marks. Recent surveys of Paddlefish in the Wisconsin River by Lyons (1993) and Runstrom et al. (2001) have likewise reported very high incidence of Silver Lamprey marks, 96% (n = 240 Paddlefish) and 83.6% (n = 315), respectively. Although the Chestnut Lamprey also occurs in Lake Pepin (Wagner 1909; Hubbs and Trautman 1937), it appears to be rare compared to Silver Lamprey, a situation similar to that found in the Ottawa River basin (Renaud and de Ville 2000). The incidence of lamprey-induced marks in this study was positively correlated with size of the Muskellunge. Intuitively, one would think that large hosts are favored because of their large blood supply and the likelihood of recovery from an attack, making them available to future events of parasitism. It is not advantageous for a parasite to kill its host. However, in his laboratory experiments, Roy (1973) determined that Silver Lamprey attachments resulted in 51.9% of the hosts being killed. Additionally, he observed that the size of the host did not confer an advantage to its survival from lamprey attacks but rather the site of attachment was the critical factor, with wounds inflicted on the head and abdomen more likely to be fatal (Roy 1973). The range in length and weight of the hosts in Roy's (1973) experiments, however, was significantly smaller than those in this study. All species combined, the lengths of the hosts varied between 8-98.9 cm and weight between 0.005 and 2.2 kg, whereas the Muskellunge in this study varied between 94-135 cm TL (n = 14) and weight between 13 and 19 kg (n = 3). There might be a threshold length or weight which confers an advantage to the survival of the host that was not reached in Roy's (1973) experiments. The cause of death of the Muskellunge in this study was not established, but a number of interesting observations were noted. It possessed 26 lamprey-induced marks, which although high were not lethal in two other cases with still higher marks. Although it possessed four marks on its ventral surface, these were healed. However, its weight was low, 13 kg for a total length of 131 cm. Furthermore, the gills on the left side were pale brown whereas the ones on the right side were dark red. One of the fishermen who was in the fishing party, Adam McLellan, reported a lamprey falling out of the branchial cavity upon landing. Perhaps, the low condition factor and the loss of blood made the Muskellunge too weak to survive the trauma of being hooked and taken out of the water. Lennon (1954) observed extensively torn gill filaments on one or more gill arches in hosts of the Sea Lamprey and suggested that the copious secretions of mucus in the branchial cavity as a result of this irritation could have impaired gill function and thereby contributed to the death of the host. No apparent damage, however, was done to the gill filaments of the Muskellunge in this study.

Although Silver Lamprey has also been known to parasitize fish as small as 25-cm TL (Goldfish: George 1985), a phenomenon reported notably by Cochran and Jenkins (1994) for other lamprey species, its preference would seem to be towards large fish hosts (i.e., greater than 30 cm TL) as indicated by its size-based differential selection of Muskellunge in this study and the fact that the majority of documented hosts (14 out of 20) are

large (Table 1), based on average lengths in Scott and Crossman (1973). Very few studies actually recorded the size of the hosts. The few that did were as follows: 130 cm TL, 16 kg *Acipenser fulvescens* (Vladykov 1985); 97-168 cm TL *Polyodon spathula* (Lyons 1993); about 25 cm TL *Carassius auratus* (George 1985); about 84 cm TL *Esox lucius* (Hubbs and Trautman 1937); 94-135 cm TL *E. masquinongy* (this study). The five hosts considered small would be the Goldfish, the Brown Bullhead, the Brook Trout, the Rock Bass and the Smallmouth Bass. The greater incidence of marks on larger Muskellunge is suggested to be attributable to two factors: their larger surface area, providing more attachment sites, and their greater age, increasing the probability of encounter. In laboratory experiments, Cochran (1985) demonstrated that a congeneric lamprey, *Ichthyomyzon castaneus,* showed statistically significant preference for host fish with larger surface areas. Additionally, slightly over half the hosts (11 out of 20) are either naked, have large scutes confined to certain areas only, or in most cases possess thin scales (Table 1). The nine hosts with thick scales would be the Longnose Gar, the Goldfish, the Common Carp, the Black Buffalo, the White Bass, the Striped Bass, the Rock Bass, the Smallmouth Bass and the Walleye. The Longnose Gar as a host for the Silver Lamprey (Bensley 1915) was confirmed in the Ottawa River (CMNFI 1999-39). Nevertheless, the typical host of the Silver Lamprey is larger than 30 cm TL and is thin scaled.

Multiple marks were found on 80% of Muskellunge in this study, a level higher than that reported for Paddlefish where 70% of 315 specimens had multiple marks (Runstrom et al. 2001). Although a single lamprey may be responsible for a number of marks on a host, there were two cases in this study where two lampreys were attached to a single Muskellunge and two cases are known, one in 1999, the other in 2001, where three lampreys were attached to a Muskellunge in the 90-km section of the Ottawa River under consideration (John Anderson, personal communication). The mean number of 1.2 lamprey attached to Muskellunge (this study) was identical to that found on Paddlefish (Lyons 1993). Some Paddlefish have been found with between 10 and 25 Silver Lampreys attached (Wagner 1909; Lyons 1993). The report by Vladykov (1985) of 61 Silver Lamprey on a Lake Sturgeon is an extreme case of multiple lampreys on a host. It is known that Muskellunge outside the spawning season (late April – early May) are both solitary and sedentary (Scott and Crossman 1973). Our material was collected during June-October, thus post-spawning. Therefore, by mapping the location of the Muskellunge with high numbers of lamprey marks, arbitrarily set at 10 marks, it appears that adult Silver Lamprey are more highly concentrated in a 50-km stretch along the lower Ottawa River, between Thurso and Hawkesbury, compared to the 40-km stretch upstream, between Ottawa and Thurso (Figure 1). Indeed, in the former case there are ten records, six of which have over ten marks (overall mean = 13.9), while in the latter there are only five records, all below ten marks (mean = 4.0).

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Ephemeral Occurrence of the Mosquito Fern, *Azolla caroliniana*, at Ottawa, Ontario

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Mosquito fern, *Azolla caroliniana*, is known in Canada only from records at Hamilton (1862) and Gananoque (1981), where it did not persist. In 1997 it was found in a pond in a residential area of central Ottawa. In 1998 is was not detected at this pond, but was found in the Rideau River through central Ottawa and into the Ottawa River on both the Ontario and Quebec shores. The enormous populations which had spread in the rivers in 1998 were completely absent in 1999.

Key Words: *Azolla caroliniana*, Mosquito Fern, invasive plants, weeds, rare plants, plant dispersal.

The fern family Azollaceae contains one genus, *Azolla*, with about five to seven extant species and a number of others known from fossil material. Commonly called mosquito ferns, they are small free-floating aquatic plants distributed in tropical and warm temperate regions throughout the world. Morphological reduction is exhibited along with various adaptations to its aquatic habitat. Copiously branched short stems bear alternate and (usually) closely imbricate leaves and a few pendulous roots. The leaves are divided into two lobes, a slightly larger, thin and translucent submersed lobe and a green or reddish emersed lobe covered with minute papillae.

Three species are native to North America with two reported in Canada, *Azolla mexicana* C. Presl in British Columbia, and *A. caroliniana* Willd. in Ontario (Cody and Britton 1989). Another species, *A. filiculoides* Lam. has been reported for southern Alaska (Svenson 1944; Lumpkin 1993) and may possibly be found in British Columbia. The distribution maps for *A. mexicana* and *A. caroliniana* in Cody and Britton (1989) have the captions inadvertently switched.

Widespread in the eastern United States, south through Central America and the West Indies to South America, *A. caroliniana* has also been introduced to Europe and Asia (Lumpkin 1993). In spite of its wide distribution, Lellinger (1985) considered it a "rare" plant. Other authors report it as common or even abundant, but, because of its rapid growth under suitable conditions, large populations can cover connected water bodies quickly, giving an illusion of widespread abundance. Although known from northern New York State (see overview in Cody and Schueler 1988), it has been found only twice in Ontario (Cody and Schueler 1988). The first collection in Canada is of plants taken at Burlington Beach (near Hamilton) in 1862. The plant does not seem to have persisted there, and has not been seen since the original collection. An extensive population found at Knights Creek (near Gananoque) in 1981 also did not persist to the following year (Cody and Schueler 1988).

Azolla caroliniana is a plant of slow-moving or stagnant water in ponds, lakes, marshes, swamps, streams, rivers, ditches, etc. (Lumpkin 1993). It is the most cold resistant species in the genus (Lumpkin 1993), and Redman (1995) reported that populations successfully over-wintered in Maryland and Washington, D.C. Studies on physiology and responses to environmental conditions have mostly been conducted on the economically important, tropical and subtropical species *A. pinnata* R. Br. and are summarized by Wagner (1997).

Species of *Azolla* are heterosporic, but reproduction in *A. caroliniana* seems to be entirely vegetative. Megaspores are unknown, although microspores are sometimes detected and are produced under conditions of crowding (Lellinger 1985).

A symbiotic relationship has formed between species of *Azolla* and the cyanobacterium (blue-green alga) *Anabaena azollae* Strasb. (and possibly other bacteria) much like the relationship between the Fabaceae (Leguminosae) and *Rhizobium* (Wagner 1997). The cyanobacterium is able to fix atmospheric nitrogen, thus providing a source of this nutrient normally unavailable to plants (Wagner 1997). Although nitrogen is not a limiting nutrient, phosphorus availability can be a major constraint on *Azolla* growth (Kushari and Watanabe 1991; Wagner 1997). Reports of minimal phosphorous concentrations required for maximum growth vary between studies as well as between species. Concentrations ranging from 400 $\mu g\ l^{-1}$ to 20,000 $\mu g\ l^{-1}$ have been reported as minimum requirements for maximum growth rates. Under optimal conditions some *Azolla* species can double their biomass in 3–5 days (Lumpkin and Plunknett 1982; Wagner 1997).

Because of the high nitrogen content, various species are used in agriculture as a green manure or biofertilizer (Lumpkin and Plucknett 1982). Some species, including *A. caroliniana*, are used as ornamental plants in aquaria and decorative pools (Lellinger 1985; L. H. Bailey Hortorium 1976). Other uses and applications are summarized by Wagner (1997). In some situations *A. caroliniana* has been a serious weed disrupting aquatic ecology and interfering with human activities (Thieret 1980). The reduction of light (up to 90%) and reduced oxygen levels (50% or more) in the water column under *Azolla* mats can have such an affect on other vegetation that it has been studied as a means of weed control in rice paddies (Wagner 1997).

Azolla caroliniana at Ottawa

In September of 1997 a population of *A. caroliniana* was found in the westerly pond of Brown's Inlet off the Rideau Canal in Ottawa, Ontario (Figure 1, site 1; Appendix 1, specimen 1). Individual plants and mats in patches up to about 0.5 m in diameter were common around the perimeter of the pond among other floating and emergent plants. Other vegetation studies in this pond during the previous two years had failed to detect the fern (personal observations).

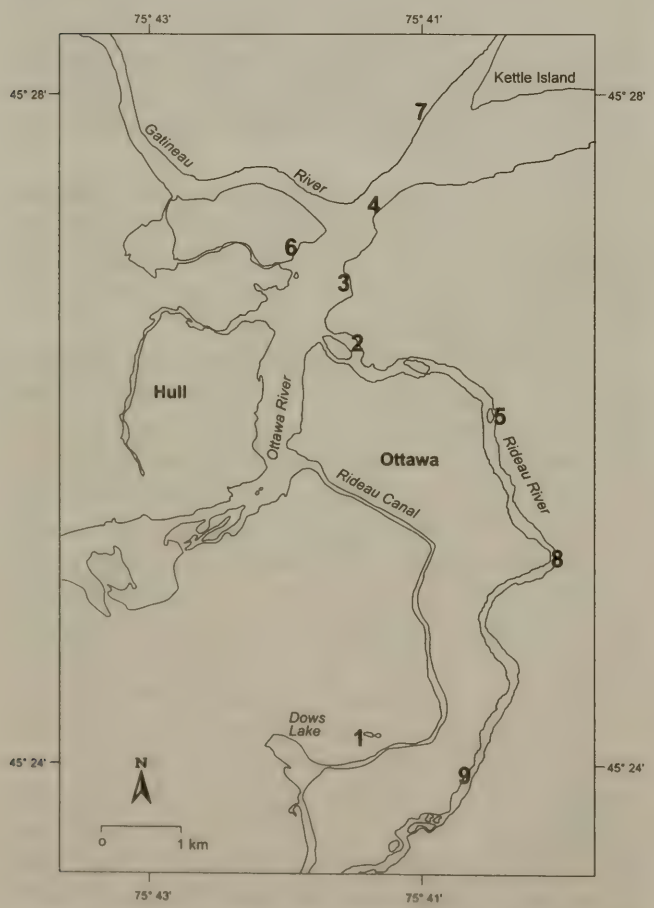

FIGURE 1. Map of the area of the Rideau and Ottawa Rivers where *Azolla caroliniana* populations occurred in 1997 and 1998. Numbers correspond to approximate locations of collections listed in Appendix 1.

The pond, being connected to the Rideau Canal system, is completely drained in the autumn (usually October) of each year. Draw-down of water in the Canal commenced on 15 October 1997. Drainage of the pond was complete by 18 October and mats of *A. caroliniana* were left stranded on the wet mud. On 19 and 20 October, daily minimum temperatures were about -3°C. The first significant snowfall occurred on October 21 (9 cm) and then again on October 26 (18 cm); however, persistent snow cover did not occur until November 15. During this time minimum temperatures of less than -5°C were recorded on six days (24, 26 and 27 October, and 12, 13 and 14 November), including the minimum of -9.4°C on 13 November. Stranded plants would have had little protection from dessication and cold temperatures for more than a month. Continued observations during the next two years did not detect *A. caroliniana* at Brown's Inlet. It is presumed that these winter conditions proved too harsh for the vegetative material to over-winter.

In late summer of 1998, colonies of *A. caroliniana* were seen in substantial mats along the shores of the Rideau River. Through the month of September surveys were conducted along the Rideau River and the Ottawa River downstream from the mouth of the Rideau River. Although a much wider area was surveyed (upstream on the Rideau River to Manotick, downstream on the Ottawa River to Cumberland, and the Rideau Canal from Mooney's Bay to the Ottawa River), *A. caroliniana* was found only between collection sites 7 and 9 (Figure 1; Appendix 1). Over this stretch of about 10 kilometres it was abundant, often completely swathing the shore for considerable distances. Mats became sparser at the upstream and downstream extremes of the distribution and where the river shores were exposed to strong currents or waves. Mats were mostly along shores and becoming thick and continuous in quiet bays and around protecting emergent vegetation such as Cattails (*Typha latifolia* L.) or Reed Canary Grass (*Phalaris arundinacea* L.). Sometimes mats would become dislodged in currents and drift downstream. In fast running water the mats would disintegrate into individual plants or small clumps, but in slow moving water contiguous mats of about a hundred square metres were sometimes seen. While not at optimum growth levels, phosphorous concentrations measured every two weeks in the Rideau River showed a plentiful supply of this nutrient as well as a peak during the major population expansion in mid-July, 1998 (Figure 2).

Systematic and repeated searches in August and September of 1999 throughout the area of the previous year's infestation failed to detect a single plant of *A. caroliniana*. Less detailed searches in 2000 were also negative. The large population seems to be the result of a single introduction at a point close to collection site number 9 (Figure 1). Figure 2

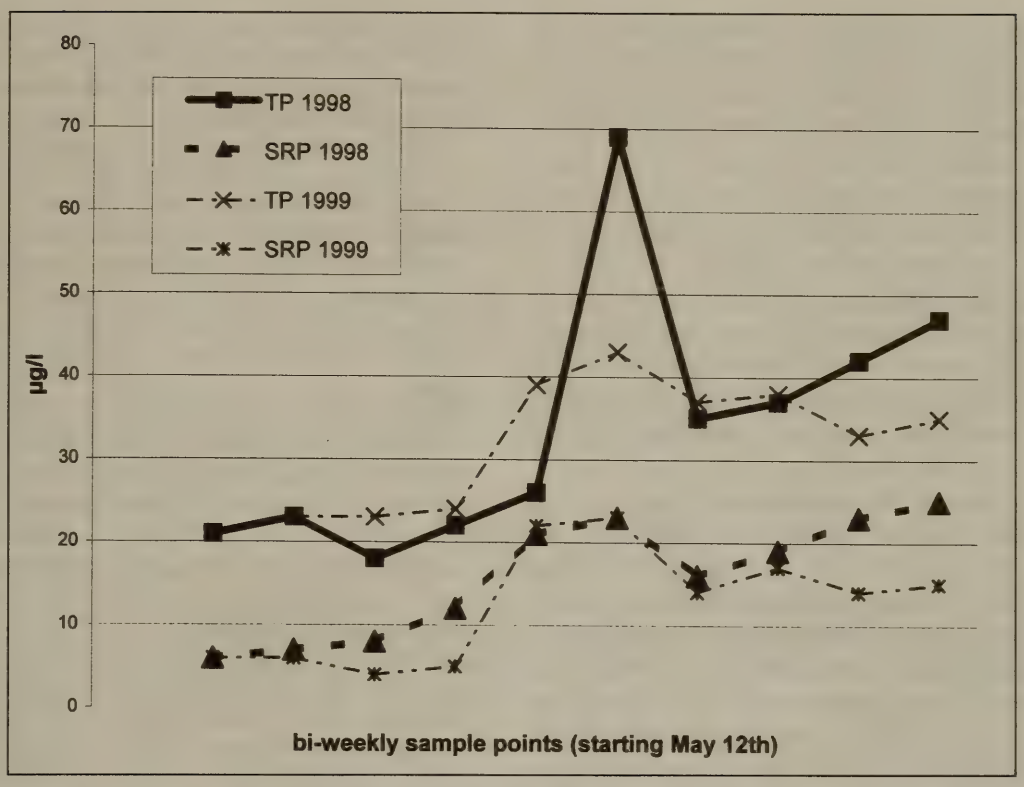

FIGURE 2. Plot of the total phosphorus (TP) and soluble reactive phosphorus (SRP) in the Rideau River during the summers of 1998 and 1999 (Paul Hamilton, personal communication). Samples were taken at 2 week intervals starting May 12 at station #103 (St. Patrick Street Bridge), about half way between points 2 and 5 on Figure 1.

indicates that phosphorous concentrations would not have been a limiting factor in 1999, so the complete disappearance is most likely the result of winter-kill.

Dispersal of *Azolla*

The west bank of the Rideau River at collection site 9 has a gentle slope allowing easy access to the water and is immediately adjacent to a small residential enclave. The introduction could have easily occurred here from the dumping of aquarium contents. Species of *Azolla* are easily and often grown in aquaria for decorative purposes and used in science teaching to demonstrate the nitrogen fixing heterocysts of the symbiotic cyanobacteria. Small (1935) considered the occurrences of *A. caroliniana* around southeastern New York State and northern New Jersey (and by implication further north) to be colonies naturalized from human introductions. Fernald (1950) also considered northern occurrences as being likely spread from cultivation.

In recent years a number of exotic aquarium-trade species have been reported as introduced into the Rideau Canal and Rideau River round Ottawa, including several tropical fish species (Renaud and Phelps 1999; Renaud and Phelps 2001) and a turtle (Darbyshire 2000). It may well be that the introduction of *A. caroliniana* into the Rideau River occurred coincidental with the dumping of fish or other aquarium animals early in season of 1998. The occurrence of the plant in Brown's Inlet (collection 1, Appendix 1) was most likely a deliberate introduction. Brown's Inlet consists of two ponds in an urban residential area. They are separated from each other and from the Rideau Canal by roadbeds, but all connected by submerged culverts. *Azolla* was found only in the upper pond which has a small municipal park on the south side and residential property to the north. Other exotic plants sold for aquaria and ponds have also been collected in this same pond. Some of these have established and persisted for many years (e.g., *Nymphoides peltata* (Gmel.) Kuntze), while others have been ephemeral (e.g., *Pistia stratiotes* L.).

Cranfill (1980), observing the ephemeral nature of populations and the species' North American distribution, speculated that *A. caroliniana* is continually re-introduced by migrating waterfowl. The most upstream site of the 1998 infestation, collection site 9, is immediately downstream from a shallow area in the Rideau River which attracts large numbers of ducks. Extensive parks with ready shore access on the east side of the river (especially immediately upstream) are popular areas for people to feed waterfowl generating an additional attraction for birds.

Ridley (1930) made some very interesting observations on the various actual and probable distribution vectors of *Azolla* species in Europe and Great Britain. In addition to river flow and flood water, he cited water-birds, frogs, and human activity as

dispersal agents. Ridley speculated that birds are the most likely vehicle for long distance travel and explanation for its presence in isolated ponds. As indirect evidence he cites the sudden appearance of *Azolla* in a small isolated pond about 0.25 miles from a larger pond in which it was abundant. Moorhens (*Gallinula chloropus*) were seen going from the larger pond to the smaller one and he claimed that this would have been the only means of transport to the small pond. He also cites a fascinating series of observations by Chateau where "toads" and/or "frogs" were seen to transport *A. caroliniana* out of pans where the fern was cultivated. Subsequently it appeared in two nearby ponds, one of which was said to be 200 metres away.

Although the fronds are reported to be able to withstand hard frosts (-5°C) and prolonged ice cover (Lumpkin 1993), *Azolla caroliniana* did not persist over the winter at Ottawa. No plants were seen during the summer of 1998 at Brown's Inlet. No plants were seen anywhere in the Rideau or Ottawa Rivers in 1999 or 2000, in spite of surveys throughout the growing season and the area of previous infestation. It is not known what mechanism brought *A. caroliniana* to the Ottawa area in two separate years at two separate locations. It is possible that it arrived early in the growing season transported from more southerly populations by migrating waterfowl. Circumstantial evidence and the prevalence of recent reports of liberated aquarium fauna and flora suggest that human agents are the most likely cause, especially in the case of Brown's Inlet.

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APPENDIX 1.

Voucher specimens of *Azolla caroliniana* Willd. collected around Ottawa 1997–1998. A complete set is deposited at the herbarium DAO (Holmgren et al. 1990) with duplicates of some collections distributed to other herbaria. Since 1998 the Ottawa-Carleton Regional Municipality has became part of the City of Ottawa and now is included in the latter name.

1. Ontario, Ottawa-Carleton Regional Municipality, Ottawa, Brown's Inlet, 45°23′55"N, 75°41′28″W, artificial pond along Rideau Canal, mats forming among patches with *Nymphoides peltata*, S. J. Darbyshire 4748, 7 September 1997.
2. Ontario, Ottawa-Carleton Regional Municipality, Ottawa, Green Island, Rideau River, 45°26′23″N, 75°41′28″W, common in shallow water among other floating/emergent vegetation, S. J. Darbyshire & P. Ouellet 4984, 30 August 1998.
3. Ontario, Ottawa-Carleton Regional Municipality, Ottawa River, Governor Bay, below 24 Sussex Drive, 45°26′45″N, 75°41′27″W, large mats in shallow bay, S. J. Darbyshire, M. Murray & Tracey McDonald 4985, 10 September 1998.
4. Ontario, Ottawa-Carleton Regional Municipality, Ottawa River across from Gatineau (Quebec), Rockcliffe Park Boathouse, 45°27′18″N, 75°41′16″W, common in sheltered waters along shore, S. J. Darbyshire, M. Murray & Tracey McDonald 4986, 10 September 1998.
5. Ontario, Ottawa-Carleton Regional Municipality, Vanier, Cummings Bridge over Rideau River, 45°25′54″N, 75°40′15″W, S. J. Darbyshire, M. Murray & Tracey McDonald 4987, 10 September 1998.
6. Quebec, Hull, Leamy Lake outflow and Ottawa River, 45°26′57″N, 75°42′19″W, shallow, quiet water near mouth of creek, common along river shore in quiet water, S. J. Darbyshire & M. Murray 4998, 29 September 1998.
7. Quebec, Gatineau, Ottawa River, near the west end of Kettle Island, 45°27′51″N, 75°40′55″W, shallow water among emergent vegetation, with *Scirpus, Pontederia, Sagittaria, Lemna, Typha*, S. J. Darbyshire & M. Murray 5000, 29 September 1998.
8. Ontario, Ottawa-Carleton Regional Municipality, Ottawa, Hurdman Bridge, Rideau River, 45°24′59″N, 75°39′53″W, large patches around *Phalaris arundinacea* and emergent vegetation, with *Spirodella*, S. J. Darbyshire & M. Murray 5001, 29 September 1998.
9. Ontario, Ottawa-Carleton Regional Municipality, Ottawa, near George McIlraith Bridge, Rideau River, 45°24′07″N, 75°40′10″W, shallow water along shore with emergent vegetation, S. J. Darbyshire & M. Murray 5002, 29 September 1998.

An additional specimen is at the Canadian Museum of Nature (CAN). This collection was made about halfway between sites 2 and 5 in Figure 1.

Ontario, Ottawa-Carleton Regional Municipality, Rideau River at the St. Patrick Street bridge, east bank just south of bridge, 45°26.2′N, 75°40.5′W, band of emergent and subemergent vegetation in area with moderate flow, hard gravel/mud substrate; small green and red floating plants, forming a mat along shore over a large area; tiny leaves, roots hanging 5–10 cm, M Richard & R. Boles 98-217, 30 September 1998.

New Records of Vascular Plants in the Yukon Territory IV

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William J. Cody, Catherine E. Kennedy, Bruce Bennett, and Valerie Loewen. 2002. New records of vascular plants in the Yukon Territory IV. Canadian Field-Naturalist 116(3): 446–474.

Two native taxa, *Crassula aquatica* and *Erysimum inconspicuum,* and two introduced taxa, *Elymus elongatus* ssp. *ponticus* and *Erysimum cheiri,* are reported new to the known flora of the Yukon Territory. Significant range extensions for 199 native and 27 introduced taxa and comments on one native taxon, *Ranunculus cooleyae*, previously reported in the Territory but omitted in the Flora, are also included.

Key Words: Vascular plants, Yukon Territory, flora, new records, range extensions, phytogeography.

Since the writing of *New Records of Vascular Plants in the Yukon Territory III* (Cody et al. 2001), a considerable number of plant specimens have been submitted to Cody for identification and confirmation, in particular from Bruce Bennett, while working for Yukon Department of Renewable Resources as a wildlife biologist volunteering for the Canadian Parks and Wilderness Society on the Wind River and in various other areas in the Territory, and Valerie Loewen while studying the vegetation adjacent to the Bonnet Plume River. In addition, the senior author spent three weeks with David Cody surveying flora adjacent to the highways in the southern part of the Territory.

This paper serves to further update the *Flora of the Yukon Territory* (Cody 1996) and *Flora of the Yukon Territory, Second Edition* (Cody 2000) along with other additional records recently published (Cody et al. 1998, 2000, 2001). The floristic information presented earlier and updated here is essential for biological research and ongoing work relating to agriculture, forestry, sustainable resource management and wildlife management. With additions of two native and two introduced species reported here the flora now includes 1163 species. The new native species are rare (as defined by Douglas et al. 1981) in the Territory.

The taxa addressed in the body of this paper appear first in a synoptic list by Yukon status in alphabetical order. The taxa are then discussed in taxonomic order, as presented in the *Flora of the Yukon Territory* with citation of specimens and other pertinent information. Common names follow Cody (1996) and Douglas et al. (1984, 1990, 1991, 1998). Two native taxa, *Crassula aquatica* and *Erysimum inconspicuum* and two introduced taxa, *Elymus elongatus* ssp. *ponticus*, *Erysimum cheiri* are reported new to the flora of the Yukon Territory. Significant range extensions within the Territory are reported for 199 native and 27 introduced taxa and comments are presented on one native taxon, *Ranunculus cooleyae*.

Synoptic List by Yukon Status

Native taxa new to the Yukon Territory (2)

Crassula aquatica
Erysimum inconspicuum

Introduced taxa new to the Yukon Territory (2)

Elymus elongatus ssp. *ponticus*
Erysimum cheiri

Range extensions of native taxa within the Yukon Territory (199)

Achillea millefolium ssp. *lanulosa*
Achillea sibirica
Allium schoenoprasum ssp. *sibiricum*
Amelanchier alnifolia
Amerorchis rotundifolia
Androsace chamaejasme ssp. *lehmanniana*
Antennaria monocephala ssp. *monocephala*
Antennaria pulcherrima
Arabis columbiana
Arabis holboellii var. *secunda*
Arabis nuttallii
Arabis pinetorum
Arctostaphylos rubra
Arctostaphylos uva-ursi
Arenaria longipedunculata
Armeria maritima ssp. *arctica*
Artemisia alaskana
Artemisia campestris
Artemisia michauxiana
Artemisia tilesii
Aster sibiricus
Astragalus alpinus
Astragalus australis
Astragalus bodinii
Astragalus williamsii
Betula glandulosa
Betula neoalaskana
Boykinia richardsonii
Bromus pumpellianus var. *arcticus*
Calamagrostis canadensis ssp. *langsdorfii*

Calamagrostis stricta ssp. *stricta*
Calla palustris
Calypso bulbosa
Campanula aurita
Campanula uniflora
Cardamine bellidifolia
Cardamine digitata
Cardamine pratensis
Carex aquatilis ssp. *aquatilis*
Carex concinna
Carex gynocrates
Carex lasiocarpa ssp. *americana*
Carex lugens
Carex misandra
Carex nardina
Carex pellita
Carex podocarpa
Carex rupestris
Carex saxatilis
Carex scirpoidea
Carex spectabilis
Carex tenuiflora
Carex vaginata
Chamaedaphne calyculata
Coeloglossum viride ssp. *bracteatum*
Corallorhiza trifida
Cornus canadensis
Cornus stolonifera
Crepis nana
Cypripedium guttatum
Cypripedium parviflorum var. *makasin*
Cystopteris fragilis
Cystopteris montana
Descurainia incisa var. *incisa*
Draba alpina
Draba borealis
Draba stenoloba
Elaeagnus commutata
Eleocharis uniglumis
Elymus calderi
Elymus glaucus
Elymus macrourus
Elymus trachycaulus ssp. *glaucus*
Elymus trachycaulus ssp. *novae-angliae*
Equisetum fluviatile
Equisetum palustre
Equisetum pratense
Equisetum scirpoides
Erigeron hyssopifolius
Erigeron lonchophyllus
Eriophorum angustifolium
Eriophorum vaginatum
Erysimum cheiranthoides
Festuca baffinensis
Festuca brachyphylla
Festuca lenensis
Festuca vivipara ssp. *glabra*
Geocaulon lividum
Geum aleppicum ssp. *strictum*
Geum macrophyllum ssp. *perincisum*
Goodyera repens
Gymnocarpium jessoense ssp. *parvulum*
Halimolobus mollis
Haplopappus macleanii
Hierochloe hirta ssp. *arctica*
Hordeum jubatum
Isoetes echinospora
Juncus alpinoarticulatus ssp. *americanus*
Juncus balticus var. *alaskanus*
Juncus castaneus ssp. *castaneus*
Juncus castaneus ssp. *leucochlamys*
Juncus triglumis ssp. *albescens*
Juniperus communis ssp. *depressa*
Juniperus horizontalis
Ledum groenlandicum
Lepidium bourgeauanum
Lesquerella arctica ssp. *calderi*
Linnaea borealis ssp. *americana*
Luzula arctica ssp. *arctica*
Luzula confusa
Luzula parviflora ssp. *parviflora*
Luzula rufescens
Luzula spicata
Lycopodium annotinum var. *pungens*
Lycopodium clavatum var. *monostachyon*
Lycopodium selago
Menyanthes trifoliata
Mertensia paniculata var. *paniculata*
Minuartia biflora
Minuartia rossii
Moehringia lateriflora
Moneses uniflora
Nuphar polysepalum
Orthilia secunda
Oxycoccus microcarpus
Oxytropis campestris ssp. *varians*
Parrya arctica
Parrya nudicaulis
Pedicularis capitata
Pedicularis langsdorfii ssp. *arctica*
Pedicularis verticillata
Petasites frigidus ssp. *frigidus*
Petasites frigidus ssp. *palmatus*
Phlox alaskensis
Picea mariana
Pinus contorta ssp. *latifolia*
Plantago eriopoda
Platanthera obtusata
Poa abbreviata ssp. *abbreviata*
Poa alpina
Poa arctica ssp. *arctica*
Poa glauca
Polemonium boreale
Polygonum buxiforme
Polygonum viviparum
Populus balsamifera ssp. *balsamifera*
Populus tremuloides
Potamogeton friesii
Potamogeton richardsonii
Potentilla anserina
Potentilla litoralis
Potentilla norvegica
Potentilla palustris
Primula mistassinica
Pyrola asarifolia
Pyrola chlorantha
Pyrola grandiflora
Ranunculus cymbalaria
Ranunculus nivalis
Ribes hudsonianum

Rorippa barbareifolia
Rorippa palustris ssp. *palustris*
Rubus arcticus ssp. *acaulis*
Rubus idaeus
Sagittaria cuneata
Salicornia europaea
Salix arbusculoides
Salix barrattiana
Salix myrtillifolia
Salix planifolia ssp. *pulchra*
Salix pseudomonticola
Salix rotundifolia ssp. *dodgeana*
Sanguisorba officinalis
Saxifraga lyallii ssp. *hultenii*
Saxifraga nivalis
Saxifraga serpyllifolia
Scheuchzeria palustris ssp. *americana*
Scutellaria galericulata var. *pubescens*
Selaginella selaginoides
Senecio atropurpureus ssp. *frigidus*
Shepherdia canadensis
Silene acaulis ssp. *subacaulescens*
Sium suave
Solidago canadensis var. *salebrosa*
Solidago simplex
Sparganium minimum
Sparganium multipedunculatum
Spiraea beauverdiana
Spiranthes romanzoffiana
Stellaria longipes
Stipa hymenoides
Taraxacum ceratophyllum
Tofieldia coccinea
Triglochin maritimum
Trisetum sibiricum ssp. *sibiricum*
Trisetum spicatum
Utricularia vulgaris ssp. *macrorhiza*
Viburnum edule
Wilhelmsia physodes

Range extensions of introduced taxa within the Yukon Territory (27)

Alopecurus pratensis
Artemisia biennis
Brassica campestris
Bromus inermis
Capsella bursa-pastoris
Chenopodium album
Festuca rubra
Festuca trachyphylla
Lepidium ramosissimum
Matricaria matricarioides
Matricaria perforata
Melilotus alba
Melilotus officinalis
Onobrynchis viciifolia
Phalaris arundinacea
Phleum pratense
Plantago major
Poa annua
Poa pratensis ssp. *pratensis*
Rheum rhaponticum
Rumex crispus
Sisymbrium altissimum
Taraxacum officinale
Thlaspi arvense
Trifolium hybridum
Trifolium pratense
Trifolium repens

Comments on native taxa in the Yukon Territory (1)

Ranunculus cooleyae

Annotated Species List

LYCOPODIACEAE

Lycopodium annotinum L. var. *pungens* (La Pylaiè) Desv., Bristly Club-moss — YUKON: open disturbed ATV trail, Wind River, McClusky Lake, 64°34.19′N 134°25.77′W, *B. Bennett 00-244*, 2 July 2000 (DAO); riparian *Picea glauca/Populus balsamifera* forest with thick moss cover, Peel River, 66°00.36′N 134°43.19′W, *B. Bennett 00-467*, 11 July 2000 (DAO).

This species is widespread in the Territory (Cody 1996) but is new to the Wind and Peel rivers.

Lycopodium clavatum L. var. *monostachyon* Hook. & Grev., Common Club-moss — YUKON: moist area between cliff and *Salix/Populus/Picea* forest, Wind River Camp #4, 65°22.89′N 135°26.1′W, *B. Bennett 00-204*, 5 July 2000 (DAO).

The specimen cited above is an extension of the known range in the Territory (Cody 1996) of about 60 kilometers from a site adjacent to the Peel River. To the southwest the nearest site adjacent to the Dempster Highway is about 175 kilometers.

Lycopodium selago L., Mountain Club-moss — YUKON: saddle in alpine, upper slope of mountain, Bonnet Plume River east of Fairchild Lake, 64°58′23″N 133°42′15″W, *V. Loewen 99-1-2*, 11 July 1999 (DAO); steep active solifluxion slope, Wind River Camp #1, 64°40.39′N 134°35.96′W, *B. Bennett 00-250*, 3 July 2000 (DAO); in deep moss in open *Picea glauca* forest, Wind River, 64°48.46′N 134°41.34′W, *B. Bennett 00-831*, 3 July 2000 (DAO); steep talus slope, Wind River Camp #4, 65°22.89′N 135°26.1′W, *B. Bennett 00-172*, 5 July 2000 (DAO).

This is a widespread species in the Territory (Cody 1996) but the specimens cited above fill in a blank area in the Wernecke Mountains area.

SELAGINELLACEAE

Selaginella selaginoides (L.) Link, Spikemoss — YUKON: amongst *Parnassia* in moss at edge of river, Wind River, McClusky Lake, 64°34.19′N 134°25.77′W, *B. Bennett 00-332*, 2 July 2000 (DAO); at muddy base of steep active solifluxion slope, Wind River Camp #2, 64°51.83′N 134°38.85′W, *B. Bennett 00-161*, 4 July 2000 (DAO).

The specimens cited above are an extension of the known range in the Territory of about 175 kilometers to the east and northeast of sites adjacent to the Dempster Highway and just north of latitude 64°N.

ISOETACEAE

Isoetes echinospora Dur., Bristle-like Quillwort —

YUKON: on shore of small pond south of Morris Lake, 60°20′N 131°40′W, *R. Rosie 2030*, 8 Sept. 1999 (DAO) (determined by D. Brunton 2000).

This is a rare species in the Yukon Territory (Douglas et al. 1981). The specimen cited above is an extension of the known range in the Territory of about 160 kilometers southwest of a site in the vicinity of Frances Lake where Rosie (1991) found it in 1979. A collection by Porsild and Breitung from Sheldon Lake adjacent to the North Canol Road originally treated as *Isoetes braunii* by Porsild (1951) and as *I. echinospora* by Cody (1996) was recently revised to *I. maritima* by Brunton and Britton (1999).

EQUISETACEAE

Equisetum fluviatile L., Water Horsetail — YUKON: slough, red rock seep near confluence with the Peel River, Wind River, 65°50′N 135°18′W, *B. Bennett 00-452*, 8 July 2000 (DAO); valley bottom, palustrine emergent sedge wetland, near small pond, Bonnet Plume River, 65°02′20″N 134°17′25″W, *V. Loewen 99-25-82*, 14 July 1999 (DAO).

Cody (1996) mapped this species throughout much of the Territory. The specimens cited above are new records for the Wind and Bonnet Plume rivers.

Equisetum palustre L., Marsh Horsetail — YUKON: edge of slough, Wind River Camp #1, 64°40.39′N 134°35.96″W. *B. Bennett 00-718*, 2 July 2000 (B. Bennett Herbarium, photo DAO); base of mountain above Bonnet Plume River, 64°59′40″N 134°03′32″W, *V. Loewen 99-8-35*, 12 July 1999 (DAO); *Larix laricina/Picea mariana/Sphagnum* bog, Peel River Camp #10, between Snake and Bonnet Plume rivers, 65°57.61′N 134°25.68′W, *B. Bennett 00-696*, 12 July 2000 (B. Bennett Herbarium, photo DAO); in sandy lake shallows at west end of Morris Lake, 60°26′N 131°43′W, *R. Rosie 2025*, 10 Sept. 1999 (DAO); *Salix/Betula* thickets, Nisutlin Delta, Colwell Bay, 60°13.11′N 132°23′W, *B. Bennett 98-656*, 28 July 1998 (DAO).

The specimens cited above extend the known range about 200 kilometers from sites adjacent to the Dempster Highway (Cody 1996) and 150 kilometers south of a site adjacent to the South Canol Road.

Equisetum pratense Ehrh., Meadow Horsetail — YUKON: in young *Populus balsamifera* riparian forest on riverbar, Taco Bar, Peel River, 66°00.15′N 134°13′W, *B. Bennett 00-398*, 13 July 2000 (DAO); Richardson Mts., in mature White Spruce/Balsam Poplar forest on floodplain of Caribou River, 66°15′40″N 135°31′28″W, *R. Rosie 2146*, 15 July 2000 (DAO); Richardson Mts., river alder, 66°50′22″N 134°56′56″W, *G. Brunner 27-00*, July 2000 (DAO); Richardson Mts., alder/rose, 66°52′N 135°50′W, *G. Brunner 20-00*, July 2000 (DAO).

The nearest site of this species to the specimens cited above known to Cody (1996) is about 175 kilometers to the northwest north of the Dempster Highway.

Equisetum scirpoides Michx., Dwarf Scouring-rush — YUKON: on steep vegetated slope above river, Wind River Camp #1, 64°40.39′N 134°35.96′W, *B. Bennett 00-719*, 2 July 2000 (B. Bennett Herbarium, photo DAO).

This species is found throughout much of the Territory (Cody 1996). The specimen cited above is intermediate between sites between the Hart and Blackstone rivers and a site adjacent to the Snake River (Cody et al. 2001).

ASPIDIACEAE

Cystopteris fragilis (L.) Bernh., Fragile Fern — YUKON: steep calcareous slopes forming moist caves with talus, east bank of Wind River near confluence of Royal Creek, 65°06.83′N 135°06.43′W, *B. Bennett 00-264*, 3 July 2000 (DAO); in calcareous talus, Peel River Site #1, 65°58.6′N 134°49.69′W, *B. Bennett 00-405*, 10 July 2000 (DAO).

The specimens cited above are extensions of the known range to the east of specimens mapped by Cody (1996) of about 75 kilometers.

Cystopteris montana (Lam.) Bernh., Mountain Bladder Fern — YUKON: moist rich river bottom with step-moss, open *Picea glauca* forest on old river terrace, Wind River Camp #6, 65°40.46′N 135°11.76′W, *B. Bennett 00-850*, 7 July 2000 (DAO).

The specimen cited above is an extension of the known range in the Territory (Cody 1996) of about 150 kilometers to the east.

Gymnocarpium jessoense (Koidz.) Koidz. ssp. *parvulum* Sarvela, Nahanni Oak Fern — YUKON: wooded steep draws with steep active talus shale under *Alnus crispa*, junction of Wind and Peel rivers, 65°50.48′N 135°18.25′W, *B. Bennett 00-813*, 8 July 2000 (DAO); in calcareous talus at edge of *Picea/Alnus* thicket, Peel River Site #1, 65°58.06′N 134°49.69′W, *B. Bennett 00-409*, 10 July 2000 (DAO).

Douglas et al. (1981) (sub. *G. robertiana*) considered this species rare in the Territory. The specimens cited above are an extension of the known range in the Territory (Cody 1996) of about 200 kilometers to the northeast from a site adjacent to the Dempster Highway.

CUPRESSACEAE

Juniperus communis L. ssp. *depressa* (Pursh) Franco, Ground Juniper — YUKON: gravel roadside, Alaska Highway 21 km NW of Lake Creek Campsite, 61°58′33.8″N 140°27′50.3″W, *Cody & Cody 37138*, 26 July 2000 (DAO).

The specimen cited above is an extension of the known distribution of this widespread species in the Yukon Territory of about 100 kilometers northwest of a site adjacent to the north end of Kluane Lake.

Juniperus horizontalis Moench, Creeping Juniper — YUKON: creek valley growing in limestone outwash, Wind River Camp #3, 65°06.83′N 135°06.43′W, *B. Bennett 00-150*, 3 July 2000 (DAO).

The specimen cited above is the northernmost yet found in the Territory. The nearest site mapped by Cody (1996) is adjacent to the Bonnet Plume River about 60 kilometers to the southeast.

PINACEAE

Picea mariana (Mill.) B.S.P., Black Spruce — YUKON: Alaska Highway, 2.3 km SE of border crossing, 62°36′05.2″N 140°58′04.9″W, *Cody & Cody 37217*, 26 July 2000 (DAO); hummocky *Picea mariana* site south of recent fire west of cat trail, upper aufeis site, Wind River, 64°58.67′N 134°47.12′W, *B. Bennett 00-307*, 4 July 2000 (DAO).

The nearest site mapped by Cody (1996) to the first location cited above is about 100 kilometers to the southeast adjacent to the Alaska Highway. The second specimen is from a site in the Wernecke Mountains intermediate between locations south of latitude 64°N and just south of the Peel River.

Pinus contorta Dougl. ex Loud. ssp. *latifolia* (Engelm.) Critchfield, Lodgepole Pine — YUKON: single tree on east side of road in shallow soil over rock on slope above road among *Salix* shrubs and *Epilobium angustifolium*, Dempster Highway Km 72.5, 1.8 km N of Tombstone Mountain Campground, *Cody et al. 37023*, 22 July 2000 (DAO); small stand of pine on both sides of highway, Alaska Highway Km 1581, 60°48.81′N 136°49.42′W, *B. Bennett 00-678*, 16 July 2000 (DAO).

The first specimen cited above is the northernmost Lodgepole Pine yet known in the Yukon Territory. It is an extension of the known range in the Territory (Cody 1996) of about 175 kilometers northwest of a site adjacent to the Klondike Highway and 160 kilometers west by northwest of a site in the vicinity of Mayo. The second specimen that is the westernmost yet found in the south is about 90 kilometers west of the vicinity of Whitehorse.

SPARGANIACEAE

Sparganium minimum (Hartm.) Fries, Small Bur-reed — YUKON: slough, No Gold Creek Horseshoe Slough, 63°26′N 135°06′W, *D. Mossop s.n.*, 1 July 1999 (B. Bennett Herbarium, photo DAO); Taye Lake, 60°56′N 136°21′W, *M. Dennington s.n.*, 21 July 1982 (DAO).

Douglas et al. (1981) considered this species rare in the Territory. The first specimen cited above is about 175 kilometers to the north of a site adjacent to the Yukon River and about 200 kilometers southeast of the vicinity of Dawson City mapped by Cody (1996). The second specimen cited above is from a site about 125 kilometers southwest of the Yukon River site mapped by Cody (1996).

Sparganium multipedunculatum (Morong) Rydb., Bur-reed — YUKON: small pond by South McQuesten River near Elsa, 63°56.2′N 135°34.4′W, *S. Withers 528*, 10 Aug. 1999 (DAO).

The specimen cited above is an extension of the known range in the Territory of about 150 kilometers east of a site near the junction of the Klondike and Dempster highways (Cody 1996).

POTAMOGETONACEAE

Potamogeton friesii Rupr., Flat-stalk Pondweed — YUKON: in small pond near lake, Aishihik Lake, 61°38′N 137°28′W, *R. Rosie 2052*, 30 July 1998 (DAO); in shallows of small upland lake, Frances Lake, 61°11′N 129°08′W, *R. Rosie 2009*, 7 July 1999 (DAO); in shallows of small slough along Frances River, *R. Rosie 2011*, 5 Aug. 1998 (DAO).

The specimens cited above are range extensions from localities in the Territory (Cody 1996): Aishihik Lake about 90 kilometers north of Haines Junction and Frances Lake about 125 kilometers north of Watson Lake.

Potamogeton richardsonii (Benn.) Rydb., Richardson's Pondweed — YUKON: pond off river, Wind River Site #2, 64°54.2′N 134°41.25′W, *B. Bennett 00-160*, 4 July 2000 (DAO).

The specimen cited above is from a location intermediate between a site just north of latitude 64°N (Cody 1996) and a site just north of latitude 66°N cited by Cody et al. (2001).

SCHEUCHZERIACEAE

Scheuchzeria palustris L. ssp. *americana* (Fern.) Hultén, Scheuchzeria — YUKON: in quaking bog near Morris Lake, 60°25′16″N 131°40′46″W, *R. Rosie 2033*, 9 Sept. 1999 (DAO).

Douglas et al. (1981) considered this species rare in the Territory. The specimen cited above is an extension of the known range in the Territory of about 175 kilometers west of a site reported by Cody et al. (1998) in the vicinity of Watson Lake.

Triglochin maritimum L., Seaside Arrow-grass — YUKON: muddy slough on riverbar, Wind River, 65°12.49′N 135°13.17′W, *B. Bennett 00-136*, 5 July 2000 (DAO); boggy tussock tundra near small pond, Wind River Camp #2, 64°51.83′N 134°38.85′W, *B. Bennett 00-815*, 4 July 2000 (DAO); in quaking bog near Morris Lake, 60°26′N 131°43′W, *R. Rosie 2034*, 10 Sept. 1999 (DAO).

The specimens cited above are extensions of the known range in the Territory (Cody 1996) of about 180 kilometers southeast of the Dempster Highway, 150 kilometers south of a site north of latitude 66°N cited by Cody et al. (2001) and intermittent between Whitehorse and Watson Lake.

ALISMATACEAE (ALISMACEAE)

Sagittaria cuneata Sheld., Arum-leaved Arrowhead — YUKON: < 50 plants seen in shallows, Little Atlin Lake, 60°17.84′N 133°59.15′W, *B. Bennett 00-592*, 30 July 2000 (DAO).

Douglas et al. (1981) considered this species rare in the Territory. The specimen cited above is an extension of the known range in the Territory (Cody 1996) from sites east and northeast adjacent to the Alaska Highway.

POACEAE

Alopecurus pratensis L., Meadow Foxtail — YUKON: gravel roadside, Alaska Highway, 21 km NW of Lake Creek Campground, 61°58′33.8″N 140°27′50.3″W, *Cody & Cody 37135, 26* July 2000 (DAO); disturbed gravel at roadstop, Alaska Highway 74 km NW of Snag Junction Campground, 62°17′16.4″N 140°46′45.5″W, *Cody & Cody 37186*, 26 July 2000 (DAO); Mechanic Creek west of Big Creek drainage, 62°20′N 137°19.5′W, *S. Withers 212*, 21 July 1999 (B. Bennett Herbarium, photo DAO).

Cody (1996) knew this introduced species from only three widely separated locations in the Territory. Cody et al. (2001) added two additional sites at Elsa and south of Whitehorse. The specimens cited above extend the known range in the Territory to near the Alaska border adjacent to the Alaska Highway and about 150 kilometers to the east of the highway.

Bromus inermis Leyss., Smooth Brome — YUKON: Lake Creek, 61°51′19.6″N 140°09′11.2″W, *Cody & Cody 37124*, 26 July 2000 (DAO); broad gravel roadside, Alaska Highway, 400 m NW of White River Bridge 61°59′27.4″N 140°33′55.6″W, *Cody & Cody 37144*, 26 July 2000 (DAO); roadside gravel slope, Alaska Highway, 20 km NW of White River Bridge, 62°08′39.6′N 140°41′05.0″W, *Cody & Cody 37160*, 26 July 2000 (DAO); Beaver Creek Community, 62°23′11.1″N 140°52′28.3″W, *Cody & Cody 37228*, 26 July 2000 (DAO).

The specimens cited above are a range extension of this introduced species in the Territory of about 200 kilometers on the Alaska Highway to near the Alaska border from a site northwest of Haines Junction (Cody 1996).

Bromus pumpellianus Scribn. var. *arcticus* (Shear) A.E. Porsild, Pumpelly Brome — YUKON: open riverbar in gravels and silt, Illytd Creek confluence with Wind River, 65°30.07′N 135°22.88′W, *B. Bennett 00-108*, 6 July 2000 (B. Bennett Herbarium, photo DAO); loose sand near top of beach, Taco Bar, Peel River, 66°00.15′N 134°13′W, *B. Bennett 00-389*, 13 July 2000 (B. Bennett Herbarium, photo DAO).

This is a widespread species in the Territory (Cody 1996) but the only specimens between latitude 64° and 66°30′N were adjacent to the Dempster Highway and to the west.

Calamagrostis canadensis (Michx.) Beauv. ssp. *langsdorfii* (Link) Hultén — YUKON: disturbed gravelly soil of lower slope of ski hill, Mt. Sima Ski Hill, Whitehorse, 60°36′41.2″N 135°02′46.6″W, *Cody & Cody 37477*, 4 Aug. 2000 (DAO); gravel slope, Alaska Highway, just east of Alaska border line, 62°36′53.8″N 140°59′59.8″W, *Cody & Cody 37195, 37196* (DAO); valley bottom near small pond, Bonnet Plume River, 65°02′20″N 134°17′25″W, *V. Loewen 99-26-83*, 14 July 1999 (DAO).

This subspecies that is widespread throughout much of the Territory (Cody 1996) has not previously been found in the vicinities of Whitehorse and the Alaska Highway near the Alaska border, and in the area between latitudes 64°N and 67°N east of the Dempster Highway from a single collection northwest of the Bonnet Plume site between the Wind and Hart rivers.

Calamagrostis stricta (Timm) Koeler ssp. *stricta*, Slimstem Reedgrass — YUKON: riverbar, Wind River Camp #6, 65°40.46′N 135°11.76′W, *B. Bennett 00-148*, 7 July 2000 (B. Bennett Herbarium, photo DAO).

The specimen cited above is an extension of the known range in the Territory (Cody 1996) of about 100 kilometers east of the Dempster Highway.

Elymus calderi Barkworth, Calder's Wild Rye — YUKON: riverbar, Wind River, 64°24.43′N 134°28.88′W, *B. Bennett 00-478*, 2 July 2000 (DAO); moderately steep east slope of west-facing cirque, Bonnet Plume River, 64°50′50″N 133°18′37″W, *V. Loewen 99-36-102*, 16 July 1999 (DAO); lower ridge, rocky slope, Upper Bonnet Plume River Drainage Site #133, 64°35′45″N 132°47′50″W, *J. Staniforth 00-088*, 8 July 2000 (DAO).

Cody (1996) knew this species in the Territory only north to latitude 64°N. Cody et al. (1998) reported a new site adjacent to the Dempster Highway. The specimens cited above are from about 260 kilometers east of the Dempster Highway.

Elymus elongatus (Host) Runemark ssp. *ponticus* (Podp.) Melderis, Tall Wheat Grass (Figure 1) — YUKON: roadside gravel at Yukon/British Columbia border, 24.5 road kilometers south of Carcross, 60°00′00.6″N 134°39′47.1″W, *Cody & Cody 37406*, 30 July 2000 (DAO).

This invasive plant which is new to the Yukon Territory originated in Turkey and was planted in the prairies as a salt-tolerant forage. It is now known from all the provinces but Newfoundland, Prince Edward Island, New Brunswick and the Northwest Territories. *Elymus elongatus* ssp. *ponticus* can be separated from *E. spicatus* as follows:

A. Glumes thin, flexible, acute; culms 10–100 cm tall; native species found on dry riverbanks and slopes ..... *E. spicatus*

A. Glumes thick, stiff, obtuse to truncate; culms 70–200 cm tall; introduced, found in disturbed sites such as roadsides ..... *E. elongatus* ssp. *ponticus*

Elymus glaucus Buckl., Western Rye Grass — YUKON: steep stony grassy slope adjacent to road on north side of Yukon River, Whitehorse, 1.1 km N of Grey Mountain cemetery, 60°42′21.0″N 134°59′52.0″W, *Cody & Cody 37422*, 31 July 2000 (DAO).

Douglas et al. (1981) considered this species rare in the Territory and has since been reported in the extreme southeast (Cody et al. 2000). The specimen cited above is an extension of the known range in the Territory of about 150 kilometers to the east from sites in the Kluane area.

Elymus macrourus (Turcz.) Tzvelev, Thick-spike Wild Rye — YUKON: between foot of cliff and road, Canol Road Km 202, 61°53′30″N 132°45′07.5″W, *Cody and Cody 36937*, 18 July 2000 (DAO).

The specimen cited above is an extension of the known range in the Territory of about 100 kilometers to the east of a site adjacent to the Yukon River (Cody 1996).

Elymus trachycaulus (Link) Gould ex Shinners ssp. *glaucus* (Pease & Moore) Cody — YUKON: borders of roads in campground by *Salix*, *Alnus* and *Picea*, Pine Valley Campground, Alaska Hwy., 61°51′14.3″N 140°08′58.9″W, *Cody & Cody 37111*, 26 July 2000 (DAO).

The specimen cited above is an extension of the known range in the Territory of about 75 kilometers to the northwest from a site at the north end of Kluane Lake (Cody 1996).

FIGURE 1. *Elymus elongatus* ssp. *ponticus*, Tall Wheat Grass (Drawn by Lee Mennell).

Elymus trachycaulus (Link) Gould ex Shinners ssp. *novae-angliae* (Scribner) Tzvelev — YUKON: disturbed gravel at roadstop, Alaska Highway 7.4 km NW of Snag Junction Campground, 62°17′16.4″N 140°46′45.5″W, *Cody & Cody 37180*, 26 July 2000 (DAO) (determined by S. J. Darbyshire).

The specimen cited above is an extension of the known range in the Territory of about 175 kilometers northwest of a site at the south end of Kluane Lake (Cody 1996).

Festuca baffinensis Polunin, Baffin Fescue — YUKON: alpine tundra, Kotaneelee Range, 60°15′N 124°08′W, *R. Rosie 2072*, 20 June 1998 (DAO); moist draw in subalpine meadow, Kotaneelee Range, 60°14.31′N 124°07.19′W, *B. Bennett 98-710*, 15 June 1998 (DAO).

The specimens cited above are an extension of the known range in the Territory (Cody 1996) of about 400 kilometers southwest of a site near Ross River.

Festuca brachyphylla Schultes & Schultes f., Short-leaf Fescue — YUKON: on sandy flats at north end of small lake, Frances Lake, 61°12′N 129°05′W, *R. Rosie 2005*, 5 July 1999 (DAO).

The specimen cited above is a extension of the known range in the Territory (Cody 1996) of about 100 kilometers west of a site just west of longitude 127°W (Cody et al. 1998).

Festuca lenensis Drob., Tundra Fescue — YUKON: This mining trench was reclaimed in 1998 using an experimental agronomic seed mix, Division Mountain near Nordenskiold, 61°19′N 136°03.5′W, *S. Withers 320*, 26 July 1999 (B. Bennett Herbarium, photo DAO); mining trench, Red Ridge, 60°21.5'N 135°04.2′W, *S. Withers 109*, 14 July 1999 (DAO).

Cody (1996) knew this species in the Yukon Territory north of latitude 67°N with a single site in the south in Kluane National Park. The specimens cited above are from about 230 kilometers northeast and 200 kilometers southeast of the Kluane site.

Festuca rubra L. sl., Red Fescue — YUKON: roadside gravel, 24.5 road kilometers south of Carcross at the Yukon/BC border, 60°00′00.6″N 134°39′47.1″W, *Cody & Cody 37405*, 30 July 2000 (DAO); borders of roads in campground by *Salix*, *Alnus* and *Picea*, Pine Valley Campground, Alaska Highway, 61°51′14.3″N 140°08′58.9″W, *Cody & Cody 37106*, 26 July 2000 (DAO); Alaska Highway 21 km NW of Lake Creek Campground, 61°58′33.8″N 140°27′50.3″W, *Cody & Cody 37134*, 26 July 2000 (DAO); broad gravel roadside, Alaska Highway, 400 m NW of White River bridge, 61°59′27.4″N 140°33′55.6″W, *Cody & Cody 37143*, 26 July 2000 (DAO); gravel at rest stop, Alaska Highway 21 km NW of White River bridge, 62°08′51.6″N 140°41′04.5″W, *Cody & Cody 37166*, 26 July 2000 (DAO).

The specimens cited above extend the known range in the Territory (Cody 1996) about 100 kilometers south from a site west of Whitehorse and about 160 kilometers northwest of the north end of Kluane Lake.

Festuca trachyphylla (Hackel) Krajina, Hard Fescue — YUKON: borders of roads in campground by *Salix*, *Alnus* and *Picea*, Pine Valley Campground, Alaska Highway, 61°51′14.3″N 140°08′18.9″W, *Cody & Cody 37104*, 26 July 2000 (DAO).

Cody (1996) knew this introduced species only from the vicinity of Dawson City where Calder and Billard collected it in 1949.

Festuca vivipara (L.) Sm. ssp. *glabra* Frederikson, Viviparous Fescue — YUKON: solifluxion plain in valley, Vuntut National Park, 68°25.45′N 138°41.27′W, *B. Bennett 00-505*, 5 Aug. 2000 (DAO).

The specimen cited above is an extension of the known range in the far north of the Territory (Cody 1996) of about 75 kilometers to the south from a site in the British Mountains.

Hierochloe hirta (Schrank) Borbas ssp. *arctica* G. Weim., Common Sweet Grass — YUKON: riverbar,

Wind River Camp #1, 64°40.39′N 134°35.96′W, *B. Bennett 00-354*, 2 July 2000 (DAO); open riverbar in gravels, Illytd Creek confluence with Wind River, 65°30.07′N 135°22.88′W, *B. Bennett 00-109*, 6 July 2000 (DAO); loose sand near top of beach, Taco Bar, Peel River, 66°00.15′N 134°13′W, *B. Bennett 00-391*, 13 July 2000 (DAO).

The specimens cited above are the first known in the Territory from east of the Dempster Highway (Cody 1996), an extension of the known range to the east of about 175 kilometers.

Hordeum jubatum L., Foxtail Barley — YUKON: gravel slope, Alaska Highway just east of Alaska border line, 62°36′52.8″N 140°59′59.8″W, *Cody & Cody 37200*, 26 July 2000 (DAO); slumping eroding banks, cobbles and silty muck, Wind River, 65°47.45′N 135°13′W, *B. Bennett 00-120* (DAO); loose talus at base of steep active scree slope, junction of Wind and Peel rivers, 65°50.48′N 135°18.25′W, *B. Bennett 00-810*, 8 July 2000 (DAO).

The specimens cited above are extensions of the known range in the Territory (Cody 1996) of about 100 kilometers to the northwest from a site on the Alaska Highway in the vicinity of the Donjek River and about 99 kilometers east of a site just east of the Hart River.

Phalaris arundinacea L., Reed Canary Grass — YUKON: French Gulch, north of Eldorado Creek drainage, 63°53.8′N 139°21.1′W, *S. Withers 332*, 28 July 1999 (B. Bennett Herbarium, photo DAO); reclaimed mining trench, Mechanic Creek, 62°20′N 137°19.5′W, *S. Withers 203*, 21 July 1999 (DAO).

Mining trenches at these sites were reclaimed in 1995 using an experimental agronomic seed mix that may have included *Phalaris arundinacea*. The nearest sites to those listed above are about 125 kilometers to the southeast adjacent to the Klondike Highway and about 250 kilometers to the north adjacent to the Dempster Highway. Douglas et al. (1981) considered this species rare in the Territory. The introduction of races of this species for reclamation may cause genetic contamination of the native race.

Phleum pratense L., Timothy — YUKON: broad gravel roadside, Alaska Highway 400 m NW of White River bridge, 61°59′27.4″N 140°33′55.6″W, *Cody & Cody 37151*, 26 July 2000 (DAO); roadside gravel slope, Alaska Highway 20 km NW of White River Bridge, 62°08′39.6″N 140°41′05.0″W, *Cody & Cody 37161*, 26 July 2000 (DAO).

The specimens cited above extend the known range of this introduced species in the Territory (Cody 1996) about 170 kilometers to the northwest from a site at the south end of Kluane Lake.

Poa abbreviata R.Br. ssp. *abbreviata,* Northern Blue Grass — YUKON: ground shrub/herb/moss-lichen, Bonnet Plume River, 64°40′06″N 133°13′20″W, *V. Loewen 99-28-90a*, 15 July 1999 (DAO).

This is a rare species in the Yukon Territory (Cody 1996). The specimen cited above is an extension of the known range in the Territory of about 320 kilometers east of a site northwest of Dawson City.

Poa alpina L., Alpine Blue Grass — YUKON: wet sand by stream, Koidern River (Edith Creek) behind the Pine Valley Campground, 61°51′19.6″N 140°09′11.2″W, *Cody & Cody 37129*, 26 July 2000 (DAO).

The specimen cited above is an extension of the known range in the Territory adjacent to the Alaska Highway of about 100 kilometers from a site near Destruction Bay (Cody 1996).

Poa annua L., Annual Blue Grass — YUKON: sandy gravel cleared area, Top of the World Highway Km 29.2, *Cody & Cody 37037*, 22 July 2000 (DAO).

This is an uncommon introduced species in the Territory (Cody 1996). It was known to Hultén (1968) from the vicinity of Dawson City but has not been found there recently. Cody et al. (1998) reported it from the Beaver River area in the southeast. It is a new introduction along the Top of the World Highway.

Poa arctica R.Br. ssp. *arctica*, Arctic Blue Grass — YUKON: moderately steep talus slope, Bonnet Plume River, 64°44′37″N 133°24′30″W, *V. Loewen 99-38-119*, 16 July 1999 (DAO).

The specimen cited above is an extension of the known range in the Territory (Cody 1996) of about 100 kilometers northeast of a site north of Mayo.

Poa glauca Vahl, Glaucous Blue Grass — YUKON: borders of roadsides in campground by *Salix*, *Alnus* and *Picea*, Pine Valley Campground, Alaska Highway, 61°59′14.3″N 140°08′58.9″W, *Cody & Cody 37109*, 26 July 2000 (DAO); broad gravel roadside, Alaska Highway 400 m NW of White River bridge, 61°59′27.4′N 140°33′55.6″W, *Cody & Cody 37142*, 26 July 2000 (DAO).

This is a widespread species in the Territory (Cody 1996) but has not previously been collected adjacent to the Alaska Highway northwest of Kluane Lake although it is known from the mountains to the west.

Poa pratensis L. ssp. *pratensis*, Kentucky Blue Grass — YUKON: Koidern River (Edith Creek) behind the Pine Valley Campground, 61°51′19.6″N 140°09′11.2″W, *Cody & Cody 37126*, 26 July 2000 (DAO).

This is a widespread introduced species in the Territory, particularly south of latitude 64°N (Cody 1996). The specimen cited above is from a new site adjacent to the Alaska Highway between Kluane Lake and the Alaska border.

Stipa hymenoides Roem. & Schult., Indian Rice Grass — YUKON: disturbed sandy area across road from snow dump, above Whitehorse on north side of Yukon River, 60°42′44.4″N 135°01′26.6″W, *Cody & Cody 36916*, 17 July 2000 (DAO).

Cody et al. (2001) reported this species new to the Yukon Territory on the basis of a specimen collected by Bennett on a sandy eroding slope beside the hydro dam at the Schwatka Lake Dam in the Yukon River at Whitehorse. The specimen cited above is from a site about 2 kilometers to the north of the site by the hydro dam.

Trisetum sibiricum Rupr. ssp. *sibiricum,* Siberian Flase Oat — YUKON: lower part of steep rocky slope

above road, Tatchun/Frenchman Road Km 28, 20 km E of Klondike Highway, 62°14′46.5″N 135°56′33.7″W, *Cody & Cody 36993*, 21 July 2000 (DAO).

This rare amphi-beringian species was previously known from only two sites in the Territory (Cody 1996): Porcupine River and Coffee Creek on the Yukon River.

Trisetum spicatum (L.) Richt., Spike Trisetum — YUKON: riverbar, Wind River Camp #4, 65°22.89′N 135°26.1′W, *B. Bennett 00-371*, 5 July 2000 (DAO).

The specimen cited above is an extension of the known range in the Territory (Cody 1996) of about 75 kilometers to the south from a site adjacent to the Bonnet Plume River just south of the Peel River.

CYPERACEAE

Carex aquatilis Wahlenb. ssp. *aquatilis*, Water Sedge — YUKON: palustrine emergent sedge wetland, valley bottom, Bonnet Plume River, 65°02′20″N 134°17′25″W, *V. Loewen 99-25-81*, 14 July 1999 (DAO); headwaters of Bonnet Plume River, Mackenzie Mountains, 64°20′N 132°35′W, *J. Meikle s.n.*, 5 Aug. 1997 (DAO); silty mud on edge of riverbank, Wind River Camp #1, 64°30.39′N 134°35.96′W, *B. Bennett 00-762*, 2 July 2000 (DAO); emergent from lake, McClusky Lake, Wind River, 64°34.19′N 134°25.77′W, *B. Bennett 00-287*, 2 July 2000 (DAO).

The specimens cited above are extensions of the known range of this species of about 75 kilometers to the northeast and about 200 kilometers to the east of a site in the Wernecke Mountains west of longitude 135°W (Cody 1996).

Carex concinna R.Br., Low Northern Sedge — YUKON: older *Picea glauca/Populus balsamifera* forest beside creek in shady mossy area, Wind River Camp #1, 64°40.39′N 134°35.96′W, *B. Bennett 00-731*, 2 July 2000 (DAO); occasional in moist *Picea glauca* woods, Wind River Camp #4, 65°22.89′N 135°26.1′W, *B. Bennett 00-261*, 5 July 2000 (DAO); open *Picea glauca* forest on old river terrace, Wind River Camp #6, 65°40.46′N 135°11.76′W, *B. Bennett 00-863*, 7 July 2000 (DAO); riparian spruce forest, Peel River Camp #10, 65°57.61′N 134°25.68′W, *B. Bennett 00-684*, 12 July 2000 (DAO).

The specimens cited above are the first known between latitudes 64°N and 66°N east of the Dempster Highway.

Carex gynocrates Wormskj., Yellow Bog Sedge — YUKON: on steep vegetated slope above river, Wind River Camp #1, 64°40.39′N 134°35.96′W, *B. Bennett 00-716*, 2 July 2000 (DAO); moderately steep east slope of west-facing cirque, Bonnet Plume River, 64°50′50″N 133°18′37″W, *V. Loewen 99-36-105*, 16 July 1999 (DAO).

The specimens cited above are an extension of the known range in the Territory (Cody 1996) of about 175 kilometers northeast of a site in the vicinity of Mayo.

Carex lasiocarpa Ehrh. ssp. *americana* (Fern.) Hultén, Wooly-fruit Sedge — YUKON: with *Carex utriculata* along small creek in wetland, Frances Lake, 61°09′N 129°07′W, *R. Rosie 2001*, 11 July 1999 (DAO).

Douglas et al. (1981) considered this species rare in the Territory. The specimens cited above are an extension of about 125 kilometers north of a site adjacent to Watson Lake reported by Cody et al. (1998).

Carex lugens Holm, Spruce Muskeg Sedge — YUKON: woodland white spruce/shrub stand near Bonnet Plume River, 64°59′48″N 134°04′10″W, *V. Loewen 99-41-134*, 16 July 1999 (DAO); severely mounded lower slope, tussock tundra-*Carex/Eriophorum*, Upper Bonnet Plume River Drainage, 64°19′23″N 131°35′9″W, *J. Staniforth 00-123, 00-125*, July 2000 (DAO).

The first specimen cited above is an extension of the known range in the Territory (Cody 1996) of about 150 kilometers to the northeast from a site in the vicinity of Mayo. The second specimen is from a site about 200 kilometers east of the Mayo area.

Carex misandra R.Br., Short-leaved Sedge — YUKON: cirque lake shore, Bonnet Plume River, 64°50′51″N 133°18′33″W, *V. Loewen 99-37-114*, 16 July 1999 (DAO); steep northeast-facing alpine slope, Bonnet Plume River, 64°54′36″N 133°34′20″W, *V. Loewen 99-10-46*, 12 July 1999 (DAO); open dolomite delta, Wind River, 64°48.46′N 134°41.34′W, *B. Bennett 00-254*, 3 July 2000 (DAO).

The specimens listed above are an extension of the known range in the Territory (Cody 1996) of about 140 kilometers to the east from a site in the Wernecke Mountains.

Carex nardina Fries, Spikenard Sedge — YUKON: moderately steep east slope of west-facing cirque, Bonnet Plume River, 64°50′50″N 133°18′37″W, *V. Loewen 99-36-103*, 16 July 2000 (DAO); steep active solifluxion slope across river from camp, Wind River Camp #1, 64°40.38′N 134°35.96′W, *B. Bennett 00-1044*, 3 July 2000 (DAO).

The specimens cited above are an extension of the known range in the Territory (Cody 1996) of about 150 kilometers northeast of a site in the vicinity of Mayo.

Carex pellita Willd. — YUKON: large patch at western edge at high water mark, sandy soil, Ear Lake, Whitehorse, 60°40.81′N 135°02.54′W, *B. Bennett 00-908*, 5 Sept. 2000 (DAO) (determined by P.M. Catling & W.J. Cody).

This is a rare species in the Territory (Cody et al. 2000). The specimen upon which this was based was collected adjacent to the Yukon River below Rink Rapids. The specimen cited above is the second collection known and is from a site about 200 kilometers southeast of Rink Rapids.

Carex podocarpa R.Br., Graceful Mountain Sedge — YUKON: exposed windy alpine knoll, Mt. Granger, 60°34.11′N 135°09.38′W, *B. Bennett 99-104*, 10 July 1999 (DAO); moderate south-facing slope, Bonnet Plume River, 64°40′06″N

133°13′20″W, *V. Loewen 99-28-89*, 15 July 1999 (DAO); steep southeast-facing alpine slope, Bonnet Plume River, 64°53′13″N 133°49′45″W, *V. Loewen 99-16-58*, 13 July 1999 (DAO); moderately steep east-facing slope east of Fairchild Lake, Bonnet Plume River, 64°58′03″N 133°41′12″W, *V. Loewen 99-4-17*, 11 July 1999 (DAO).

The first specimen cited above is new to the area adjacent to Whitehorse (Cody 1996) and the remaining specimens are an extension of the known range in the Territory of about 100 kilometers north of a site just north of latitude 64°N.

Carex rupestris All., Curly or Rock Sedge — YUKON: steep northeast-facing alpine slope, Bonnet Plume River, 64°54′44″N 133°33′54″W, *V. Loewen 99-11-52*, 12 July 1999 (DAO); undulating lower slope, *Dryas* outwash floodplain, Upper Bonnet Plume Drainage Site #110, 64°32′10″N 132°19′40″W, *J. Staniforth 00-054*, 6 July 2000 (DAO); steep active solifluxion slope across river from camp, Wind River Camp #1, 64°40.39′N 134°35.96′W, *B. Bennett 00-176*, 3 July 2000 (DAO).

The specimens cited above are an extension of the known range in the Territory (Cody 1996) of about 275 kilometers east of a site adjacent to the Blackstone River.

Carex saxatilis L., Russet Sedge — YUKON: sparse low white spruce/*Dryas*/cottongrass/moss, Bonnet Plume River, 64°59′40″N 134°03′32″W, *V. Loewen 99-8-32, 99-8-37*, 12 July 1999 (DAO).

The specimens cited above are an extension of the known range in the Territory (Cody 1996) of about 150 kilometers to the northeast from a site in the vicinity of Mayo.

Carex scirpoidea Michx., Single-spike Sedge — YUKON: riverbar, shrubby *Salix*, Wind River Camp #1, 64°44.43′N 134°28.88′W, *B. Bennett 00-210*, 2 July 2000 (DAO); riverbar, Wind River, raven nest site, 65°12.49′N 135°13.17′W, *B. Bennett 00-1049*, 5 July 2000 (B. Bennett Herbarium); *Betula neoalaskana/Salix scouleriana/S. bebbiana/Alnus crispa* upland esker in gravelly soil, Wind River Camp #6, 65°40.46′N 135°11.76′W, *B. Bennett 00-864*, 7 July 2000 (DAO); steep southeast-facing upper slope, Bonnet Plume River, *V. Loewen 99-29-85, 99-29-84*, 15 July 1999 (DAO); moderately steep east slope of west-facing cirque, Bonnet Plume River, 64°50′50″N 133°18′37″W, *V. Loewen 99-36-104*, 16 July 1999 (DAO); alpine ridge between two cirques, 64°51′31″N 133°34′50″W, *V. Loewen 99-9-44a, 99-9-44b*, 12 July 1999 (DAO).

The specimens cited above are intermediate between sites mapped by Cody (1996) on the Upper Bonnet Plume River and adjacent to the Hart River.

Carex spectabilis Dewey, Northern Show Sedge — YUKON: in alpine meadow, Morris Lake, 60°23′N 131°33′W, *R. Rosie 2021*, 11 Sept. 1999 (DAO).

This species was considered rare in the Territory by Douglas et al. (1981) who reported it from the Peel River and southeastern Kluane National Park and cited the map in Hultén (1968). That map however did not include a Peel River site and was not included in Cody (1996). The Morris Lake site is an extension of about 340 kilometers east of the Kluane area.

Carex tenuiflora Wahlenb., Sparse-leaved Sedge — YUKON: in hummock spruce with *Betula glandulosa* with open ponds of standing water, Wolf Lake, 60°42.6′N 131°44.08′W, *B. Bennett 99-331*, 11 Aug. 1999 (DAO).

The specimen cited above is an extension of the known range in the south of the Territory (Cody 1996) of about 125 kilometers northwest of a site west of Watson Lake adjacent to the Alaska Highway.

Carex vaginata Tausch., Sheathed Sedge — YUKON: alpine ridge between two cirques, Bonnet Plume River, 64°54′31″N 133°34′50″W, *V. Loewen 99-9-43*, 12 July 1999 (DAO); moist rivulet on east-facing mountain, Wind River Camp #1, 64°30.39′N 134°35.96′W, *B. Bennett 00-722*, 2 July 2000 (DAO); on hummocky *Picea/Salix* near river, Wind River, McClusky Lake, 64°34.19′N 134°25.77′W, *B. Bennett 00-330*, 2 July 2000 (DAO); moist area below cliff with springs, Wind River Camp #4, 65°22.89′N 135°26.1′W, *B. Bennett 00-842*, 5 July 2000 (DAO).

The specimens cited above are an extension of the known range in the Territory (Cody 1996) of about 170 kilometers northwest from a site adjacent to the Upper Bonnet Plume River.

Eleocharis uniglumis (Link) Schult., Creeping Spike-rush — YUKON: graminoid/sedge meadows at edge of lake out to mud flats, south end of Stevens Lake, 61°41′40.14″N 137°30′12.63″W, *Staniforth & Rosie 98-167*, 28 Aug. 1998 (DAO).

Douglas et al. (1981) considered this species rare in the Territory. This specimen cited above is intermediate between sites near Haines Junction and Carmacks (Cody 1996).

Eriophorum angustifolium Honckn., Narrow-leaved Cotton-grass — YUKON: boggy tussock tundra near small pond, Wind River Camp #2, 64°51.83′N 134°38.85′W, *B. Bennett 00-816*, 4 July 2000 (DAO); cirque lake shore, Bonnet Plume River, 64°50′51″N 133°18′33″W, *V. Loewen 99-37-107*, 16 July 1999 (DAO); moderate southeast-facing slope of creek valley on east-facing mountain slope, Bonnet Plume River, 64°53′27″N 133°48′01″W, *V. Loewen 99-19-72*, 13 July 1999 (DAO); Bonnet Plume Lake, 64°20′N 132°W, *W.H. Butler & N. Olsen 22*, 11-27 July 1966 (CAN).

The specimens cited above of this widespread species in the Territory (Cody 1996) are the first known from between latitudes 64°N and 66°N east of the Dempster Highway.

Eriophorum vaginatum L., Sheathed Cotton-grass — YUKON: base of mountain above Bonnet Plume River, 64°59′40″N 134°03′32″W, *V. Loewen 99-8-36*, 12 July 1999 (DAO); tussock meadow near creek in Bonnet Plume River Valley, 64°54′49″N

133°44′05″W, *V. Loewen 99-39-125*, 16 July 1999 (DAO); severely mounded lower slope, tussock tundra, Upper Bonnet Plume River Drainage Site #140, 64°18′23″N 131°35′9″W, *J. Staniforth 00-124*, July 2000 (DAO).

The specimens cited above are an extension of the known range of this widespread species in the Territory (Cody 1996) of about 250 kilometers to the southeast from a site south of the Peel River between the Wind and Hart rivers.

ARACEAE

Calla palustris L., Wild Calla — YUKON: No Gold Creek, Horseshoe Slough, 63°26′N 135°06′W, *D. Mossop s.n.*, 1 July 1999 (DAO).

This is a frequent species in the vicinity of the Porcupine River but is rare in the Territory south of latitude 67°N. The specimen cited above is an extension of about 50 kilometers to the southeast from the vicinity of Mayo.

JUNCACEAE

Juncus alpinoarticulatus Chaix in Vill ssp. *americanus* (Farwell) Hamet-Ahti, Alpine Rush — YUKON: moist sandy gravel shore of Long Lake, Whitehorse, 60°44′38.8″N 135°02′47.2″W, *Cody & Cody 37461*, 3 Aug. 2000 (DAO); silty seep at edge of river, Peel River Site #1, 65°58.06′N 134°49.69′W, *B. Bennett 00-404*, 10 July 2000 (DAO).

The nearest sites to the first specimen cited above known to Cody (1996) were southwest of Johnson's Crossing about 100 kilometers to the east and in Kluane National Park about 100 kilometers to the west. The second specimen is intermediate between a site in the vicinity of Mayo and the Porcupine River.

Juncus balticus Willd. var. *alaskanus* (Hultén) A.E. Porsild, Baltic Rush — YUKON: riverbar, Wind River Camp #1, 64°34.43′N 134°28.88′W, *B. Bennett 00-473*, 2 July 2000 (DAO); silty mud on edge of lake, Wind River Camp #2, 64°51.83′N 134°38.85′W, *B. Bennett 00-827*, 4 July 2000 (DAO); muddy slough on riverbar, Wind River, 65°12.49′N 135°13.17′W, *B. Bennett 00-457*, 5 July 2000 (B. Bennett Herbarium, photo DAO).

The specimens cited above are intermediate between sites mapped by Cody (1996) adjacent to the Dempster Highway and upper Bonnet Plume River.

Juncus castaneus Smith ssp. *castaneus*, Chestnut Rush — YUKON: in hummocky *Picea/Salix* forest near river, McClusky Lake, Wind River, 64°34.19′N 134°25.77′W, *B. Bennett 00-337*, 2 July 2000 (DAO).

The specimen cited above is intermediate between sites mapped by Cody (1996) adjacent to the Dempster Highway, upper Bonnet Plume River and just south of latitude 64°N.

Juncus castaneus Smith ssp. *leucochlamys* (Zinz.) Hultén — YUKON: riverbar at base of cliff, Wind River, 65°12.49′N 135°13.17′W, *B. Bennett 00-367*, 5 July 2000 (DAO).

The nearest site known to Cody (1996) to the specimen cited above is in the vicinity of Mayo about 175 kilometers to the south.

Juncus triglumis L. ssp. *albescens* (Lange) Hultén, Whitish Rush — YUKON: riverbar, Wind River near confluence of Royal Creek, 65°06.83′N 134°47.12′W, *B. Bennett 00-196*, 4 July 2000 (DAO); muddy slough on riverbar, Wind River, 65°12.49′N 135°13.17′W, *B. Bennett 00-137*, 5 July 2000 (DAO).

The specimens cited above are intermediate between sites adjacent to the upper Bonnet Plume River and between the Blackstone and Hart rivers mapped by Cody (1996).

Luzula arctica Blytt ssp. *arctica*, Arctic Woodrush — YUKON: open meadow near outfitter's camp, Wind River, McClusky Lake, 64°34.19′N 134°25.77′W, *B. Bennett 00-242*, 2 July 2000 (DAO).

The specimen cited above is intermediate between sites at about 64°N and 66°N mapped by Cody (1996).

Luzula confusa Lindebl., Confused Woodrush — YUKON: moderate south-facing slope, Bonnet Plume River, 64°40′06″N 133°13′20″W, *V. Loewen 99-28-91*, 15 July 1999 (DAO); moderately steep talus slope, Bonnet Plume River, 64°44′37″N 133°24′30″W, *V. Loewen 99-38-123, 99-38-120*, 16 July 1999 (DAO).

The specimens cited above are an extension of the known range in the Territory (Cody 1996) of about 100 kilometers to the northeast from a site just south of 64°N.

Luzula parviflora (Ehrh.) Desv. ssp. *parviflora*, Small-flowered Woodrush — YUKON: moist disturbed area by river's edge, McClusky Lake, Wind River, 64°34.19′N 134°25.77′W, *B. Bennett 00-284*, 2 July 2000 (DAO); undulating lower slope, Upper Bonnet Plume River Drainage Site #104, 64°26′15″N 132°15′47″W, *J. Staniforth 00-027*, 5 July 2000 (DAO); strongly mounded undulating alpine valley lower slope, Upper Bonnet Plume River Drainage Site #154, 64°28′19″N 132°19′21″W, *J. Staniforth 00-154*, 12 July 2000 (DAO); undulating upper slope, moist hummocky tundra, Upper Bonnet Plume River Drainage Site #108, 64°28′05″N 132°04′15″W, *J. Staniforth 00-037*, 5 July 2000 (DAO).

The specimens cited above are an extension of the known range in the Territory (Cody 1996) of about 100 kilometers north-northeast of a site south of latitude 64°N and 140 kilometers northeast of the same site.

Luzula rufescens Fisch. & Mey., Rusty Woodrush — YUKON: in willow shrub/birch/*Festuca altaica* stand on Frances River floodplain, 61°11′N 129°13′30″W, *R. Rosie 2006*, 19 June 1999 (DAO).

The specimen cited above is an extension of the known range in the Territory (Cody 1996) of about 350 kilometers east of a site north of Aishihik Lake.

Luzula spicata (L.) DC., Spiked Woodrush — YUKON: moderately steep east-facing alpine slope east of Fairchild Lake, Bonnet Plume River, 64°58′09″N 133°41′56″W, *V. Loewen 99-2-10*, 11 July 1999 (DAO).

The specimen cited above is an extension of the known range in the Territory (Cody 1996) of about 140 kilometers northeast of sites south of latitude 64°N and is the northernmost yet found.

LILIACEAE

Allium schoenoprasum L. ssp. *sibiricum* (L.) Celak, Wild Onion — YUKON: open riverbar in gravels, Wind River, 65°30.07′N 135°22.88′W, *B. Bennett 00-107*, 6 July 2000 (B. Bennett Herbarium, photo DAO); riverbar on tributary stream in gravels, Wind River, 65°46.36′N 135°10.71′W, *B. Bennett 00-124*, 8 July 2000 (DAO); riverbar, Peel River Camp #8, 65°56.03′N 134°58.84′W, *B. Bennett 00-767*, 9 July 2000 (DAO).

The specimens cited above are intermediate between sites mapped by Cody (1996) south of latitude 64°N and north of latitude 67°N.

Tofieldia coccinea Richards., Northern False Asphodel — YUKON: talus slope near river, Deception Mtn., Wind River, 65°36.03′N 135°28.41′W, *B. Bennett 00-424*, 7 July 2000 (DAO); shallow soil over limestone, Snake River, 65°24′N 133°24′W, *J. Meikle 99-008*, 20 July 1999 (Yukon Renewable Resources, photo DAO); steep solifluxion slope, Wind River Camp #1, 64°40.39′N 134°35.96′W, *B. Bennett 00-174*, 3 July 2000 (DAO); steep northeast-facing slope, Bonnet Plume River, 64°54′44″N 133°33′54″W, *V. Loewen 99-11-50*, 12 July 1999 (DAO).

The specimens cited above are intermediate between sites mapped by Cody (1996) and a site adjacent to the Snake River (Cody et al. 2001).

ORCHIDACEAE

Amerorchis rotundifolia (Banks) Hultén, Round-leaved Orchis — YUKON: moist *Picea glauca/Alnus* thicket, riparian with seeps, Peel River Site #1, 65°58.06′N 134°49.69′W, *B. Bennett 00-402*, 10 July 2000 (DAO); riparian *Picea glauca/Populus balsamifera/Alnus incana* forest, Deception Mountain, Wind River, 65°36.03′N 135°28.41′W, *B. Bennett 00-273*, 7 July 2000 (DAO); wet area between talus and *Picea glauca/Alnus incana* woods, Wind River Camp #4, 65°22.89′N 135°26.1′W, *B. Bennett 00-259*, 5 July 2000 (DAO); steep moist draw in *Populus tremuloides/Picea glauca/Ledum groenlandicum* stand in subalpine, Wind River Camp #3, 65°06.83′N 135°06.43′W, *B. Bennett 00-151*, 3 July 2000 (DAO).

The specimens cited above extend the known distribution of this species in the Territory (Cody 1996) south into the Wernecke Mts. about 110 kilometers from two sites just north of latitude 66°N.

Calypso bulbosa (L.) Oakes, Fairy-slipper – YUKON: open *Picea glauca* forest on old river terrace, Wind River Camp #6, 65°40.46′N 135°11.76′W, *B. Bennett 00-253*, 7 July 2000 (B. Bennett Herbarium, photo DAO).

The specimen cited above is an extension of the known range in the Territory of about 250 kilometers north of the vicinity of Mayo and about 290 kilometers northeast of the vicinity of Dawson City (Cody 1996).

Coeloglossum viride (L.) Hartm. ssp. *bracteatum* (Muhl.) Hultén, Bracted Green Orchid — YUKON: deciduous shrub-*Salix/Betula/* ericaceous shrubs, Donjek Burn, 61°30′N 139°36′W, *C.E. Kennedy s.n.*, 26 June 1985 (Yukon Renewable Resources, photo DAO); riverbar, Wind River Camp #3, 65°06.83′N 134°47.12′W, *B. Bennett 00-192*, 4 July 2000 (DAO).

Douglas et al. (1981) considered this species rare in the Territory and was known to Cody (1996) from only two widely separated localities: adjacent to Atlin Road in the extreme south and adjacent to the Bonnet Plume River far to the north. Cody et al. (2001) reported a specimen from the Snake River to the east of the Bonnet Plume River. The Wind River collection is from west of the Bonnet Plume River site. The Donjek Burn collection is from a site about 350 kilometers northwest of the Atlin Road site.

Corallorhiza trifida Chat., Striped Coralroot — YUKON: *Picea mariana/Betula papyrifera/Sphagnum* bog on top of bluffs, junction of Wind and Peel rivers, 65°50.48′N 135°18.25′W, *B. Bennett 00-112*, 9 July 2000 (DAO); riverbar, Wind River Camp #1, 64°40.39′N 134°35.96′W, *B. Bennett 00-355*, 2 July 2000 (DAO); in hummocky *Picea/Salix* forest near river, McClusky Lake, Wind River, 64°34.19′N 134°25.77′W, *B. Bennett 00-375*, 2 July 2000 (DAO).

This is a widespread species in the Territory (Cody 1996) but was previously unknown east of the Dempster Highway between latitudes 64°N and 66°N.

Cypripedium guttatum Sw., Spotted Lady's-slipper — YUKON: moist areas well up on slope with *Larix laricina*, Deception Mountain, Wind River, 65°36.03′N 135°28.41′W, *B. Bennett 00-426*, 7 July 2000 (DAO); moist glade in *Picea glauca* forest above open dolomite delta, Wind River, 64°48.46′N 134°41.34′W, *B. Bennett 00-254*, 3 July 2000 (DAO).

Douglas et al. (1981) considered this species rare in the Territory. The specimens cited above extend the known range in the Territory south into the Wernecke Mountains about 120 kilometers from a site near the Peel River (Cody 1996).

Cypripedium parviflorum Salisb. var. *makasin* (Farwell) Sheviak (Sheviak 1993) (*C. calceolus* L. ssp. *parviflorum* (of recent authors), Small Yellow Lady's-slipper — YUKON: moist wooded slope growing in talus, Wind River Camp #3, 65°06.83′N 134°47.12′W, *B. Bennett 00-214*, 4 July 2000 (DAO); moist areas well up on slope with *Larix laricina*, Deception Mountain, Wind River, 65°36.03′N 135°28.41′W, *B. Bennett 00-270*, 7 July 2000 (B. Bennett Herbarium, photo DAO).

Douglas et al. (1981) considered this species rare in the Territory. Cody (1996) knew it from only four localities: vicinity of Faro, two adjacent to the Bonnet Plume River and adjacent to the Alaska border at 66°N. Cody et al.

(2000) extended the known range to the northeast of the Alaska border site.

Goodyera repens (L.) R.Br., Dwarf Rattlesnake-plantain — YUKON: wet moss under spruce, Alaska Highway, 2.3 km SE of border crossing, 62°36′05.2″N 140°58′04.9″W, *Cody & Cody 37214*, 26 July 2000 (DAO).

The nearest site of this orchid species to the locality in the Territory is about 75 kilometers due south adjacent to the Alaska border (Cody 1996).

Platanthera obtusata (Pursh) Lindl., Northern Bog Orchid — YUKON: Riparian *Picea glauca/Populus balsamifera/Alnus incana* forest, Deception Mountain, Wind River, 65°36.03′N 135°28.41′W, *B. Bennett 00-425*, 7 July 2000 (DAO); at base of steep talus slope beside muddy seep, Wind River Camp #4, 65°22.89′N 135°26.1′W, *B. Bennett 00-856*, 5 July 2000 (DAO); *Picea glauca* riparian forest, Wind River Camp #1, 64°40.39′N 134°35.96′W, *B. Bennett 00-361*, 2 July 2000 (DAO); undulating spruce/shrub/lowshrub/forb/moss area, Upper Bonnet Plume River Drainage near Site #105, 64°26′6″N 132°15′28″W, *J. Staniforth 00-011*, 5 July 2000.

The specimens cited above are from sites up to about 100 kilometers west and northwest and southeast from a site adjacent to the Snake River reported by Cody et al. (2001), the only other known location between latitudes 64°N and 66°N east of the Dempster Highway.

Spiranthes romanzoffiana Cham. & Schlecht., Hooded Ladies′-tresses — YUKON: wet moss, Aishihik Lake, Km 42 on Aishihik road from Alaska Highway, 61°11′38.3″N 136°59′54.9″W, *Cody & Cody 37312*, 29 July 2000 (DAO).

The specimen cited above is from a site intermediate between the vicinity of Whitehorse about 100 kilometers to the southeast and a site adjacent to the Alaska Highway about 200 kilometers to the northwest (Cody 1996).

SALICACEAE

Populus balsamifera L. ssp. *balsamifera*, Balsam Poplar — YUKON: older *Picea glauca/Populus balsamifera* forest beside creek, Wind River Camp #1, 64°40.39′N 134°35.96′W, *B. Bennett 00-727*, 2 July 2000 (DAO).

The specimen cited above is an extension of the known range in the Territory (Cody 1996) of about 125 kilometers to the northeast from a site in the vicinity of Mayo.

Populus tremuloides Michx., Trembling Aspen — YUKON: open stand in steep draw in subalpine, Wind River Camp #3, 65°06.83′N 135°06.43′W, *B. Bennett 00-149*, 3 July 2000 (DAO); steep open slope, Deception Mountain, Wind River, 65°36.03′N 135°28.41′W, *B. Bennett 00-274*, 7 July 2000 (DAO).

The specimens cited above are intermediate between sites mapped by Cody (1996) between the vicinity of Mayo and latitude 66°N.

Salix arbusculoides Anderss., Northern Bush Willow — YUKON: moist rich river bottom with step-moss, open *Picea glauca* forest on old river terrace, Wind River Camp #6, 65°40.46′N 135°11.76′W, *B. Bennett 00-851*, 7 July 2000 (DAO); riparian forest, Wind River, 65°12′49″N 135°13′17″W, *B. Bennett 00-139*, 5 July 2000 (DAO); loose talus at base of steep active shale scree slope, junction of Wind and Peel rivers, 65°50.48′N 135°18.25′W, *B. Bennett 00-804*, 8 July 2000 (DAO); older *Populus balsamifera/Salix* forest beside creek between Snake and Bonnet Plume rivers, Peel River Camp #9, 65°58.13′N 134°48.61′W, *B. Bennett 00-793, 00-791*, 10 July 2000 (DAO); edge of river in older *Salix alaxensis/S. pulchra/Calamagrostis canadensis* meadow, Peel River Camp #10, 65°57′61″N 134°25′68″W, *B. Bennett 00-713*, 12 July 2000 (DAO); woodland white spruce/shrub stand near Bonnet Plume River, 64°59′48″N 134°04′10″W, *V. Loewen 99-41-132*, 17 July 1999 (DAO) (determined by G. Argus).

The specimens cited above are an extension of the known range in the Territory of about 150 kilometers from sites adjacent to the Dempster Highway.

Salix barrattiana Hook., Barratt's Willow — YUKON: base of mountain above Bonnet Plume River, 64°59′40″N 134°03′32″W, *V. Loewen 99-8-40*, 12 July 1999 (DAO); wetland undulating valley floor sedge meadow, Upper Bonnet Plume River Drainage Site #142, 64°22′47″N 132°07′52″W, *J. Staniforth 00-133*, 10 July 2000 (DAO); shrub meadow valley bottom, Upper Bonnet Plume River Site #146, 64°22′26″N 132°46′40″W, *J. Staniforth 00-143*, 10 July 2000 (DAO); undulating upper slope, moist hummocky tundra, Upper Bonnet Plume River Drainage Site #108, 64°28′05″N 132°04′11″W, *J. Staniforth 00-038*, 5 July 2000 (DAO); valley floor, moist shrub/graminoid/moss, Upper Bonnet Plume River Drainage Site #114, 64°24′51″N 132°23′W, *J. Staniforth 00-065*, 6 July 2000 (DAO); riverbar, Wind River, Camp #1, 64°34′43″N 134°28′88″W, *B. Bennett 00-267*, 2 July 2000 (DAO) (determined by G. Argus).

The specimens cited above are an extension of the known range in the Territory (Cody 1996) of about 250 kilometers east of sites between the Hart and Blackstone rivers.

Salix myrtillifolia Anderss., Bilberry Willow — YUKON: marshy area near river, McClusky Lake, Wind River, 64°34.19′N 134°25.77′W, *B. Bennett 00-241*, 2 July 2000 (DAO); older *Picea glauca/Populus balsamifera* forest beside creek, Wind River Camp #1, 64°40.39′N 134°35.96′W, *B. Bennett 00-749*, 2 July 2000 (DAO); base of mountain above Bonnet Plume River, 64°59′40″N 134°03′32″W, *V. Loewen 99-8-38*, 12 July 1999 (DAO) (determined by G. Argus).

The specimens cited above are an extension of the known range in the Territory of about 75 kilometers to the north of a site just north of latitude 64°N (Cody 1996).

Salix planifolia Pursh ssp. *pulchra* (Cham.) Argus — YUKON: moderately steep N-facing slope, Bonnet Plume River, 65°01′48″N 134°18′55″W, *V. Loewen 99-23-77*, 14 July 1999 (DAO); tussock meadow near creek in Bonnet Plume River valley, 64°54′49″N 133°44′05″W, *V. Loewen 99-39-124*, 16 July 1999 (DAO); open meadow and shrubby area near outfitter's camp, McClusky Lake, Wind River, 64°34.19′N 134°25.77′W, *B. Bennett 00-312, 00-234*, 2 July 2000 (DAO) (determined by G. Argus).

The specimens cited above are an extension of the known range in the Territory (Cody 1996) of about 100 kilometers to the north of a site just north of latitude 64°N.

Salix pseudomonticola Bebb (*S. monticola* sensu Cody 1996), Mountain Willow — YUKON: edge of river in older *Salix alaxensis/S. pseudomonticola/S. pulchra/Calamagrostis* meadow, Peel River Camp #10 between Snake and Bonnet Plume rivers, 65°57.61′N 134°25.68′W, *B. Bennett 00-871*, 12 July 2000 (DAO) (determined by G. Argus).

The specimen cited above is the northernmost yet found in the Territory (Cody 1996). It is from about 275 kilometers north of a site in the vicinity of Mayo.

Salix rotundifolia Trautv. ssp. *dodgeana* (Rydb.) Argus — YUKON: moderately steep southwest-facing slope, Bonnet Plume River, 64°41′30″N 133°05′15″W, *V. Loewen 99-30-87*, 15 July 1999 (DAO) (determined by G. Argus).

The specimen cited above is an extension of the known range in the Territory (Cody 1996) of about 100 kilometers to the southeast.

BETULACEAE

Betula glandulosa Michx., Ground Birch — YUKON: on steep vegetated slope above river, Wind River Camp #1, 64°40.39′N 134°35.96′W, *B. Bennett 00-755*, 2 July 2000 (DAO).

The specimen cited above is an extension of the known range in the Territory (Cody 1996) of about 120 kilometers northeast from a site north of Mayo.

Betula neoalaskana Sarg., Alaska Birch — YUKON: edge of *Picea* between low *Salix*, Alaska Hwy. 2.3 km SE of border crossing, 62°36′05″N 140°58′04.9″W, *Cody & Cody 37219*, 26 July 2000 (DAO).

This is a widespread species in the Territory north to just beyond latitude 68°N. The specimen cited above is from a location about 60 kilometers northwest of a site adjacent to the Alaska Highway (Cody 1996).

SANTALACEAE

Geocaulon lividum (Richards.) Fern., Northern Comandra — YUKON: steep vegetated slope above river, Wind River Camp #1, 64°40.39′N 134°35.96′W, *B. Bennett 00-701*, 2 July 2000 (DAO).; hummocky *Picea mariana* site south of recent fire west of cat trail, Wind River, 64°58.67′N 134°47.12′W, *B. Bennett 00-306*, 4 July 2000 (DAO).

The specimens cited above are from sites about 75 kilometers south of a location adjacent to the Bonnet Plume River cited by Cody et al. (2000).

POLYGONACEAE

Polygonum buxiforme Small, Eastern Knotweed — YUKON: gravel disturbed area, Alaska Highway at Destruction Bay, 61°15′07.6″N 138°48′19.8″W, *Cody & Cody 37069*, 25 July 2000 (DAO); gravel beside Alaska Highway, Beaver Creek Community, 62°23′11.1″N 140°52′28.3″W, *Cody & Cody 37224*, 26 July 2000 (DAO).

This native weedy species which is found as far north adjacent to the Dempster Highway to north of latitude 66°N (Cody 1996) is now known northwest of the vicinity of Haines Junction adjacent to the Alaska Highway near the Alaska border.

Polygonum viviparum L., Alpine Bistort — YUKON: amongst *Salix* on riverbar, Wind River, 65°12.49′N 135°13.17′W, *B. Bennett 00-458*, 5 July 2000 (DAO); on steep vegetated slope above river, Wind River Camp #1, 69°40.39′N 134°35.96′W, *B. Bennett 00-738*, 2 July 2000 (DAO).

The specimens cited above are intermediate between a site adjacent to the Snake River to the east (Cody et al. 2001) and a site adjacent to the Hart River to the west.

Rheum rhaponticum L., Rhubarb — YUKON: growing wild in town area, Destruction Bay, 61°15′10.2″N 138°40′00.5″W, *Cody & Cody 37233*, 27 July 2000 (DAO).

Cody et al. (2001) reported Rhubarb growing wild at Silver City on the east side of the south end of Kluane Lake.

Rumex crispus L., Curled Dock — YUKON: waste ground along roadside, Alaska Highway, 16.5 km W of Klondike Highway, 60°51′34.2″N 135°28′24.8″W, *Cody & Cody 37052*, 24 July 2000 (DAO); gravel waste area, Haines Junction, 60°45′06.7″N 137°30′28.7″W, *Cody & Cody 37062*, 25 July 2000 (DAO); gravel slope, Alaska Highway, just east of Alaska border line, 62°36′52.8″N 140°59′59.8″W, *Cody & Cody 37208, 37209*, 26 July 2000 (DAO).

Cody (1996) knew this species that was introduced from Europe only from the vicinity of Dawson City.

CHENOPODIACEAE

Chenopodium album L., Lamb's-quarters — YUKON: disturbed outfitter camp, Wind River Camp #2, 64°45.05′N 134°38.75′W, *B. Bennett 00-185*, 3 July 2000 (DAO).

The specimen cited above of this introduced species is an extension of the known range of about 150 kilometers to the northeast from a site adjacent to Mayo (Cody 1996).

Salicornia europaea L., Slender Glasswort — YUKON: dry narrow meadow between rock outcrops, Albert Rock's grazing lease, south of Deep Creek rock, Lake Laberge, 61°03′29.1′N 135°11′44.4″W, *P. Smith 00-865*, 10 Aug. 2000 (DAO).

Douglas et al. (1981) considered this species rare in the Territory. Cody (1996) knew it from only two localities

adjacent to the Alaska Highway. The specimen cited above is an extension of the known range of about 60 kilometers to the northeast.

CARYOPHYLLACEAE

Arenaria longipedunculata Hultén, Low Sandwort — YUKON: alpine tundra, Aishihik L. area, 61°57′N 37°50′W, *R. Rosie 2042*, 15 Aug. 1999 (DAO).

Cody (1996) knew this species from widely scattered areas in the Territory. The specimen cited above is from a locality about 140 kilometers north of a site in Kluane National Park.

Minuartia biflora (L.) Schinz. & Thell., Mountain Sandwort — YUKON: alpine ridge between two cirques, Bonnet Plume River, 64°54′31″N 133°34′50″W, *V. Loewen 99-9-43a*, 12 July 1999 (DAO).

The specimen cited above is an extension of the known range in the Territory (Cody 1996) of about 160 kilometers to the northeast of sites south of latitude 64°N.

Minuartia rossii (R.Br.) Graebn., Ross′ Stitchwort — YUKON: alpine barren on ridge of mountain summit west of camp, Vuntut National Park, 68°27.52′N 138°46.02′W, *B. Bennett 00-519*, 7 Aug. 2000 (DAO); vicinity of Snowdrift Camp, Vuntut National Park, 68°21.4′N 139°13.1′W, *P. Caswell PPC-2000-Y-102*, 20 June 2000 (B. Bennett Herbarium, photo DAO).

Cody (1996) knew this species in the southwest of the Territory and adjacent to the Arctic coast. The specimens cited above are an extension of about 70 kilometers to the southwest into the mountains.

Moehringia lateriflora (L.) Fenzl, Blunt-leaved Sandwort — YUKON: midslope shrub zone, Upper Bonnet Plume River Drainage Site #150, 64°30′7″N 133°01′36″W, *J. Staniforth 00-146*, 11 July 2000 (DAO); loose talus at top of steep active shale slope, junction of Wind and Peel rivers, 65°50.48′N 135°18.25′W, *B. Bennett 00-802*, 8 July 2000 (DAO); talus at base of cliff, Taco Bar, Peel River, 65°55′N 134°15′W, *B. Bennett 00-386*, 12 July 2000 (DAO); alder/rose, Richardson Mts., 66°44′51″N 135°24′40″W, *G. Brunner 24C-00*, July 2000 (DAO).

The specimens cited above are intermediate between sites adjacent to the Dempster Highway and Porcupine River (Cody 1996) and a site adjacent to the Snake River (Cody et al. 2001).

Silene acaulis L. ssp. *subacaulescens* (F. N. Williams) Hultén, Moss Campion — YUKON: on steep vegetated slope above river, Wind River Camp #1, 64°40.39′N 134°35.96′W, *B. Bennett 00-753*, 2 July 2000 (B. Bennett Herbarium, photo DAO).

The specimen cited above is an extension of the known range in the Territory (Cody 1996) of about 120 kilometers northeast from a site north of Mayo.

Stellaria longipes Goldie, Long-stalked Starwort – YUKON: moderately steep north-facing slope, Bonnet Plume River, 65°02′03″N 134°19′09″W, *V. Loewen 99-24-78*, 14 July 1999 (DAO); open meadow near outfitter′s camp, Wind River, McClusky Lake, 64°34.19′N 134°25.77′W, *B. Bennett 00-311, 00-350*, 2 July 2000 (DAO).

The specimens cited above are intermediate between a site just east of the Hart River (Cody 1996) and a site adjacent to the Snake River (Cody et al. 2001).

Wilhelmsia physodes (Fisch.) McNeill — YUKON: edge of river, McClusky Lake, Wind River, 64°34.19′N 134°25.77′W, *B. Bennett 00-335*, 2 July 2000 (DAO); riverbar at base of cliff, Wind River, 65°12.49′N 135°13.17′W, *B. Bennett 00-364*, 5 July 2000 (DAO); open riverbar in gravels, Illytd Creek confluence with Wind River, 65°30.07′N 135°22.88′W, *B. Bennett 00-104*, 6 July 2000 (B. Bennett Herbarium, photo DAO); riverbar of tributary stream in gravels, Wind River, 65°46.36′N 135°10.71′W, *B. Bennett 00-126*, 8 July 2000 (B. Bennett Herbarium, photo DAO); riverbar in cobbles, Peel River Camp #10 between Snake and Bonnet Plume rivers, 65°57.61′N 134°25.68′W, *B. Bennett 00-705*, 12 July 2000 (DAO).

This species is frequent adjacent to the Dempster Highway between latitudes 64° and 66° (Cody 1996) but with the exception of a single collection from the upper Bonnet Plume River was unknown to the east.

NYMPHAEACEAE

Nuphar polysepalum Engelm., Yellow Water-lily — YUKON: shallow water near lakeshore, Enger Lakes, 62°14′23.7″N 140°40′52.8″W, *Cody & Cody 37176*, 26 July 2000 (DAO).

The specimen cited above is an extension to the known range in the Territory of about 150 kilometers to the vicinity of the Alaska Highway in the southwest from a site adjacent to the junction of the Yukon and Stewart rivers (Cody 1996).

RANUNCULACEAE

Ranunculus cooleyae Vasey & Rose, Plume Anemone (Figure 2).

Martha Louise Black (1944) in her book of Yukon Wild Flowers included a photograph of this Buttercup and provided the following information: "We found these flowers for the first time in Yukon last summer. Mr. Porsild of the Dominion botanical staff, tells me this plant is entirely new to the Yukon. The name Plume Anemoneae comes from the beautifully plume like arrangement of the stamens. The flower is ivory white, the stamens lemon yellow, the pistils a deeper yellow. Skelly, a prospector friend at Carcross, first brought our attention to this newcomer. I must here pay a tribute to that friend who has often helped us in our search for local wild flowers". This species was not included in the *Flora of the Yukon Territory* (Cody 1996) and unfortunately has not yet been rediscovered.

Ranunculus cymbalaria Pursh, Northern Seaside Buttercup — YUKON: open disturbed area, south end of Canol Road, 60°29′26.0″N 133°17′42.0″W, *Cody & Cody 36927*, 18 July 2000 (DAO).

FIGURE 2. *Ranunculus cooleyae* (Drawn by Valerie Fulford).

The specimen cited above is an extension of the known range in the Territory of about 115 kilometers to the east from a site in the vicinity of Whitehorse (Cody 1996).

Ranunculus nivalis L., Snow Buttercup — YUKON: along wet trail dominated by sedge, Larsen Lake, 60°07′00″N 125°33′40″W, *V. Loewen 99-2*, 12 June 1999 (DAO); alpine meadow near camp, Beavercrow Ridge, 60°12.9′N 124°35.79′W, *B. Bennett 98-647*, 16 Aug. 1998 (B. Bennett Herbarium).

The specimens cited above are an extension of the known range in the Territory (Cody 1996) of about 320 kilometers southeast of a site in the vicinity of Frances Lake.

BRASSICACEAE (CRUCIFERAE)

Arabis columbiana Macoun, Elegant Rockcress — YUKON: broken rocky slope between highway and Windy Arm Tagish Lake, 1.3 km north of B.C. border, 60°00′25.9″N 134°38′40.03″W, *Cody & Cody 37414*, 30 July 2000 (DAO); Quill Creek, Kluane National Park, 60°40′N 137°22′W, *P. Caswell PPC-2000-Y-196*, 17 July 2000 (Yukon Renewable Resources, photo DAO) (determined by G. A. Mulligan).

The first specimen of this rare species in the Territory cited above is only the third yet known. The nearest site to those cited above is in the vicinity of Carmacks (Cody 1996) about 175 kilometers northeast of the Kluane National site.

Arabis holboellii Hornem. var. *secunda* (Howell) Jepson, Holboell's Rockcress — YUKON: disturbed gravelly soil at foot of ski hill, Mt. Sima Ski Area, Whitehorse, 60°36′41.2″N 135°02′46.6″W, *Cody & Cody 37471*, 4 Aug. 2000 (DAO); top of slope above Long Lake, 3.8 km on Wickstrom/Long Lake road from Hospital Rd. intersection, 60°44′38.8″N 135°02′47.2″W, *Cody & Cody 37455A*, 3 Aug. 2000 (DAO) (determined by G. A. Mulligan).

The specimens cited above are an extension of the known range of this variety in the Territory of about 100 kilometers southeast from the nearest known site adjacent to the Klondike Highway (Cody 1996).

Arabis nuttallii Robins., Nuttall's Rockcress — YUKON: mossy meadow adjacent to Coal River Springs, 61°03′31″N 127°23′42″W, *J. Staniforth s.n.*, 9 June 1996 (determined by G. A. Mulligan); old experimental farm (Warden Hq.) NW of Haines Junction, 60°46′N 137°35′W, *P. Caswell PPC-2000-Y-228*, 14 June 2000 (DAO); Horse Trail 1 km NW of old experimental farm, 60°46′N 137°37′W, *P. Caswell PPC-2000-Y-236*, 10 June 2000 (DAO).

This is a rare species in the Territory which Cody (1996) knew from only two localities. Three additional sites were added by Cody et al. (2001). The specimens cited above are an extension of about 450 kilometers east of Whitehorse.

Arabis pinetorum Tidestrom — YUKON: gravel roadside, Tagish Road 14 km W of Jakes Corner, 60°19′05.4″N 134°10′08.6″W, *Cody & Cody 37389B*, 30 July 2000 (DAO) (determined by G. A. Mulligan).

The specimen cited above is an extension of the known range in the Territory of about 100 kilometers southeast of a site northeast of Whitehorse (Cody 1996).

Brassica campestris L. (*B. rapa* sensu Cody 1996), Bird Rape — YUKON: disturbed farm area, Mayo, 63°35.26′N 135°51.83′W, *B. Bennett 00-380*, 2 July 2000 (B. Bennett Herbarium, photo DAO).

The specimen cited above is an extension of the known range of this introduced species in the Territory (Cody 1996) of about 150 kilometers southeast from a site near the south end of the Dempster Highway.

Capsella bursa-pastoris (L.) Medic, Shepherd's-purse — YUKON: gravel at rest stop, Alaska Highway, 21 km NW of White River Bridge, 62°08′51.6″N 140°41′04.5″W, *Cody & Cody 37168B*, 26 July 2000 (DAO); disturbed gravel at roadstop, Alaska Highway 7.4 km NW of Snag Junction Campground, 62°17′16.4″N 140°46′45.5″W, *Cody & Cody 37184*, 26 July 2000 (DAO); disturbed outfitter camp, Wind River Camp #2, 134°38.75′N 64°45.05′W, *B. Bennett 00-187*, 3 July 2000 (DAO) (determined by G. A. Mulligan).

The specimens cited above are extensions of the known range of this introduced species in the Territory (Cody 1996) adjacent to the Alaska Highway of about 225 kilometers northwest of Haines Junction and about 130 kilometers northeast of the vicinity of Mayo.

Cardamine bellidifolia L., Alpine Bitter-cress — YUKON: moderately steep talus slope, Bonnet Plume River, 64°44′37″N 133°24′30″W, *V. Loewen 99-38-122*, 16 July 1999 (DAO) (determined by G. A. Mulligan).

The specimen cited above is an extension of the known range in the Territory (Cody 1996) of about 50 kilometers to the east from a site adjacent to the Wind River.

Cardamine digitata Richards., Richardson's Rock-cress — YUKON: moist area below cliff with springs, Wind River Camp #4, 65°22.89′N 135°26.1′W, *B. Bennett 00-840*, 5 July 2000 (DAO); exposed rocky alpine slope, with seepages, Upper Blackstone River at Horn Claims, 64°27.1′N 138°38.2′W, *S. Withers SW00-64*, 14 July 2000 (DAO).

The first specimen cited above of this amphi-beringian species is an extension of the known range in the Territory (Cody 1996) of about 150 kilometers east of sites adjacent to the Dempster Highway. The second specimen is the southernmost yet found in the Territory and is from about 40 kilometers south of the nearest Dempster Highway site.

Cardamine pratensis L., Cuckoo Bitter-cress — YUKON: marshy area near lake, McClusky Lake, Wind River, 64°34.19′N 134°25.77′W, *B. Bennett 00-236*, 2 July 2000 (B. Bennett Herbarium, photo DAO); moist area below cliff with springs, Wind River Camp #4, 65°22.89′N 135°26.1′W, *B. Bennett 00-838*, 5 July 2000 (B. Bennett Herbarium, photo DAO) (determined by G. A. Mulligan).

The specimens cited above are intermediate between sites adjacent to the Dempster Highway and upper Bonnet Plume River (Cody 1996).

Descurainia incisa (Engelm. ex A. Gray) Britton var. *incisa*, Tansy Mustard — YUKON: roadside gravel slope, Alaska Highway, 20 km NW of White River bridge, 62°08′39.6″N 140°41′05.0″W, *Cody & Cody 37159*, 26 July 2000 (DAO); disturbed gravel at roadstop, Alaska Highway, 7.4 km NW of Snag Junction Campground, 62°17′16.4″N 140°46′45.5″W, *Cody & Cody 37182, 37183*, 26 July 2000 (DAO); gravel slope, Alaska Highway just east of Alaska border line, 62°36′53.8″N 140°59′59.8″W, *Cody & Cody 37197*, 26 July 2000 (DAO) (determined by G. A. Mulligan).

Cody et al. (2001) reported this species as new to the Territory from three widely separated localities. The specimens cited above are an extension of the known range of about 450 kilometers northwest of a site in the vicinity of Crag Lake on the Tagish Road.

Draba alpina L., Alpine Draba — YUKON: alpine, mud, shale moderate south-facing slope, *V. Loewen 99-28-94*, 15 July 1999 (DAO) (determined by G. A. Mulligan).

The nearest site in the Territory known to Cody (1996) to the specimen cited above is adjacent to the Dempster Highway about 225 kilometers to the west.

Draba borealis DC., Northern Draba — YUKON: alpine tundra, Kotaneelee Range, 60°15′N 124°08′W, *R. Rosie 2068*, 20 June 1998 (DAO); along ridge, Beavercrow Ridge, 60°13.629′N 124°32.28′W, *B. Bennett 98-651*, 15 Aug. 1998 (DAO) (determined by G. A. Mulligan).

The specimens cited above are an extension of the known range in the Territory of about 180 kilometers to the southeast of a site west of longitude 127° reported by Cody et al. (1998).

Draba stenoloba Ledeb., Alaska Whitlow-grass — YUKON: moist meadow, Coal River area, 60°51′33″N 127°40′49″W, *J. Staniforth s.n.*, 6-9 June 1996, (DAO); vicinity of Snowdrift Camp, Vuntut National Park, 68°21.4′N 139°13.1′W, *P. Caswell PPC-2000-Y-051*, 26 June 2000 (DAO) (determined by G. A. Mulligan).

Cody (1996) knew this species in the southern part of the Territory north to about 63°N and then disjunct to the western part of the British Mountains. The first specimen cited above is an extension of the known range in the Territory (Cody 1996) of about 280 kilometers to the southeast from a site adjacent to the North Canol Road. The second specimen is from a site about 130 kilometers southeast of the British Mountains site.

Erysimum cheiranthoides L., Wormseed Mustard — gravelly disturbed roadside near tramway, Alaska Highway, Km 1890, 62°02′23″N 140°36′55″W, *B. Bennett 97-215*, 3 June 1997 (DAO); gravel roadside, Alaska Highway, 17 km NW of White River bridge, 62°07′24.9″N 140°30′35.3″W, *Cody & Cody 37154*, 26 July 2000 (DAO) (determined by G. A. Mulligan).

The specimens cited above are from locations about 180 kilometers northwest of a site at the south end of Kluane Lake and west about 170 kilometers of a site adjacent to a tributary of the Kluane River mapped by Cody (1996).

Erysimum cheiri (L.) Crantz, Common Wallflower (Figure 3) — YUKON: between Robert Service Way and old railway in grass adjacent to *Picea* and *Populus* about 1.3 km from Alaska Highway, Whitehorse, 60°42′14.4′N 135°03′10.8″W, *Cody & Cody 37439*, 1 Aug. 2000 (DAO) (determined by G. A. Mulligan).

This species is a new introduction into the Yukon Territory. It is an infrequent garden escape on southeastern Vancouver Island, British Columbia (Douglas et al. 1998) which was introduced from Europe. *Erysimum cheiri* can be separated from *E. angustatum* as follows:

A. Stem leaves linear, crowded, canescent from dense malpighiaceous hairs; caudex usually multicipital; plants < 20 cm tall; petals bright yellow . . . . . *E. angustatum*

A. Stem leaves mostly lanceolate to oblanceolate, more or less entire, pubescent with malpighiaceous hairs; caudex with one or a few stems; plants usually more than 20 cm tall; petals orange-yellow . . . . . *E. cheiri*

Erysimum inconspicuum (S. Wats.) MacMill., Shy Wallflower (Figure 4) — YUKON: gravel soil by track below steep rocky slope, Tagish Rd. Km 38, 60°15′09.2″N 134°29′07.3″W, *Cody & Cody 37398*, 30 July 2000 (DAO) (determined by G. A. Mulligan).

On the basis of the revision of specimens from the Yukon Territory and Continental Northwest Territories formerly identified as *Erysimum inconspicuum* to *E. coarctatum*, Cody et al. (2000) removed *E. inconspicuum* from the flora of the Territory. On the basis of the specimen cited above, *E. inconspicuum* should now be placed back in the flora of the Yukon (Cody 1996) and added to the list of rare species in the Territory (Douglas et al. 1981).

Halimolobus mollis (Hook.) Rollins, Soft Halimolobus — YUKON: roadside gravel slope, Alaska

FIGURE 3. *Erysimum cheiri*, Common Wallflower, (Drawn by Lee Mennell).

FIGURE 4. *Erysimum inconspicuum*, Shy Wallflower (Drawn by Lee Mennell).

Highway 20 km NW of White River bridge, 62°08′39.6″N 140°41′05.0″W, *Cody & Cody 37158*, 26 July 2000 (DAO) (determined by G. A. Mulligan).

The specimen cited above is an extension of the known distribution in the Territory of about 190 kilometers northwest of a site between Haines Junction and Kluane Lake (Cody 1996).

Lepidium bourgeauanum Thell., Bourgeau's Pepper-grass — YUKON: gravel cleared area, Faro, 62°13′59.1″N 133°20′57.3″W, *Cody & Cody 36975*, 20 July 2000 (DAO); gravel slope, Alaska Highway just east of Alaska border line, 62°36′52.8″N 140°59′59.8″W, *Cody & Cody 37211*, 26 July 2000 (DAO) (determined by G. A. Mulligan).

The Faro specimen cited above is an extension of the known range in the Territory of about 175 kilometers north from Johnsons Crossing and the Alaska Highway specimen is an extension of the known range adjacent to the highway of about 60 kilometers from south of latitude 62°N (Cody 1996).

Lepidium ramosissimum A. Nelson, Branched Pepper-grass — YUKON: roadside gravel, Burwash Landing, Alaska Highway, 61°21′17.5″N 139°00′04.6″W, *Cody & Cody 37093*, 25 July 2000 (DAO); old experimental farm NW of Haines Junction, 60°46′N 137°35′W, *P. Caswell PPC-2000-Y-404*, 17 July 2000 (DAO) (determined by G. A. Mulligan).

Previously known sites of this introduced species in the Territory were in the vicinity of Tagish, and adjacent to the Klondike Highway (Cody 1996) and adjacent to Frenchman Lake (Cody et al. 2001). The specimens cited above are the first known from adjacent to the Alaska Highway.

Lesquerella arctica (Wormskj.) S. Wats. ssp. *calderi* (Mulligan & Porsild) Hultén, Arctic Bladderpod — YUKON: steep loose eroding vegetated hillside above river, Wind River, 64°56.67′N 134°47.12′W, *B. Bennett 00-297*, 4 July 2000 (B. Bennett Herbarium, photo DAO); talus slope near river, Deception Mountain, Wind River, 65°36.03′N 135°28.41′W, *B. Bennett 00-276*, 7 July 2000 (DAO); riverbar, Peel River Camp #8, 65°56′N 134°58.84′W, *B. Bennett 00-778*, 9 July 2000 (DAO); cobbly silty riverbar,

Peel River Camp #9, 65°58.13′N 134°48.61′W, *B. Bennett 00-795*, 10 July 2000 (DAO).

The specimens cited above are the easternmost yet found in the Territory (Cody 1996).

Parrya arctica R.Br., Arctic False Wallflower — YUKON: alpine mud shale moderate south-facing slope, Bonnet Plume River, 64°40′06″N 133°13′20″W, *V. Loewen 99-28-93*, 15 July 1999 (DAO) (determined by G. A. Mulligan).

Cody (1996) knew this species that is an endemic of the Arctic Archipelago only from Herschel Island about 600 kilometers northwest of this Bonnet Plume River site.

Parrya nudicaulis (L.) Regel, Northern Parrya — riverbar, Wind River, 64°34.43′N 134°28.88′W, *B. Bennett 00-480*, 2 July 2000 (DAO); on steep vegetated slope above river, Wind River Camp #1, 64°40.39′N 134°35.96′W, *B. Bennett 00-739*, 2 July 2000 (B. Bennett Herbarium, photo DAO); high alpine in loose talus, Wind River, 64°48.46′N 134°41.34′W, *B. Bennett 00-447*, 3 July 2000 (B. Bennett Herbarium, photo DAO); steep northeast-facing alpine slope, Bonnet Plume River, 64°54′36″N 133°34′20″W, *V. Loewen 99-10-48*, 12 July 1999 (DAO); woodland white spruce/ shrub stand near Bonnet Plume River, 64°59′50″N 134°04′17″W, *V. Loewen 99-40-126*, 17 July 1999 (DAO); convex lower ridge, dry well drained rocky slope, Upper Bonnet Plume River Drainage Site #132, 64°31′19″N 132°51′32″W, *J. Staniforth 00-094*, 7 July 2000 (DAO) (determined by G. A. Mulligan).

The specimens cited above extend the known range in the Territory (Cody 1996) about 130 kilometers to the east from a site just west of longitude 135°W.

Rorippa barbareifolia (DC.) Kitagawa, Hoary Yellow Cress — YUKON: gravel at rest stop, Alaska Highway, 21 km NW of White River bridge, 62°09′51.6″N 140°41′04.5″W, *Cody & Cody 37164*, 26 July 2000 (DAO); slope below rest area, Alaska Highway 18 km SE of border crossing, 62°29′57.9″N 140°51′48.4″W, *Cody & Cody 37222*, 26 July 2000 (DAO) (determined by G. A. Mulligan).

Previous collections of this amphi-beringian species in the Territory were all from north of latitude 63°N (Cody 1996). The nearest site to the specimens cited above is about 150 kilometers to the northeast.

Rorippa palustris (L.) Besser ssp. *palustris*, Marsh Yellow Cress — YUKON: gravel at the Dry Creek rest stop, Alaska Highway, 21 km NW of White River bridge, 62°08′51.6″N 140°41′04.5″W, *Cody & Cody 37168A*, 26 July 2000 (DAO) (determined by G. A. Mulligan).

The specimen cited above is an extension of about 150 kilometers northwest of sites adjacent to Kluane Lake (Cody 1996).

Sisymbrium altissimum L., Tumble Mustard — YUKON: gravel at the Dry Creek rest stop, Alaska Highway, 21 km NW of White River bridge, 62°08′51.6″N 140°41′04.5″W, *Cody & Cody 37170*, 26 July 2000 (DAO) (determined by G. A. Mulligan).

This introduced species was previously known in the Territory only from the vicinities of Dawson City and Whitehorse (Cody 1996).

Thlaspi arvense L., Penny Cress — YUKON: open meadow, McClusky Lake, Wind River, 64°34.19′N 134°25.77′W, *B. Bennett 00-283*, 2 July 2000 (DAO).

The specimen cited above extends the known range of this introduced species in the Territory about 100 kilometers northeast of a site in Keno (Cody et al. 2001). It was rare at McClusky Lake and not observed elsewhere adjacent to the Wind and Peel rivers.

CRASSULACEAE

Crassula aquatica (L.) Schoenl., (*Tillaea aquatica* L.), Pigmyweed (Figure 5) — YUKON: on shore along the road to town, Nares Lake, Carcross, 60°10′N 134°42′W, *Ceska & Goward 11765*, 6 July 1982 (DAO); shore of river, N side of bridge across Tagish River, Carcross, 60°10′N 134°42′W, *Ceska & Goward 11932*, 8 July 1982 (DAO).

This species is new to the Flora of the Yukon Territory

FIGURE 5. *Crassula aquatica*, Pygmyweed (Drawn by Lee Mennell).

and should be added to the list of rare species (Douglas et al. 1981). Elsewhere in the Canadian north it is only known from the vicinity of Yellowknife (Cody 1954). The genus Crassula can be separated from *Rhodiola* and *Sedum* as follows:

A. Plants terrestrial perennials; flowers 4 or 5 parted; stamens usually 10
   B. Flowers dioecious, 4-parted ..... *Rhodiola*
   B. Flowers perfect, 5-parted ..... *Sedum*
A. Plants of vernal pools and shallow water, annuals; flowers usually 4-parted; stamens 4 ..... *Crassula*

SAXIFRAGACEAE

Boykinia richardsonii (Hook.) A. Gray, Richardson's Boykinia — YUKON: growing in moist crag in limestone, Jasper Canyon, Snake River, 65°24′N 133°24′N, *J. Meikle 99-028, 99-029*, 20 July 1999 (Yukon Renewable Resources, photos DAO).

The specimens cited above extend the known range in the Territory about 80 kilometers north of a site adjacent to the Bonnet Plume River (Cody 1996).

Ribes hudsonianum Richards., Northern Black Currant — YUKON: *Larix laricina/Picea mariana, Carex media, Eriophorum vaginatum* marsh, Peel River Camp #10 between Snake and Bonnet Plume rivers, 65°57.61′N 134°25.68′W, *B. Bennett 00-701*, 12 July 2000 (DAO).

The specimen listed above is an extension of the known range in the Territory (Cody 1996) of about 200 kilometers to the southeast from a site east of the Porcupine River.

Saxifraga lyallii Engler. ssp. *hultenii* (Calder & Savile) Calder & Taylor, Red-stemmed Saxifrage — YUKON: moderately steep north-facing slope about mid-way up mountain, Bonnet Plume River, 64°51′10″N 133°27′41″W, *V. Loewen 99-5-21*, 11 July 1999 (DAO).

The specimen cited above is the northernmost yet found in the Territory (Cody 1996). It is from a site about 110 kilometers northwest of a site adjacent to the upper Bonnet Plume River.

Saxifraga nivalis L., Alpine Saxifrage — YUKON: alpine tundra, Kotaneelee Range, 60°15′N 124°08′W, *R. Rosie 2075*, 20 June 1998 (DAO).

The specimen cited above is an extension of the known range in the Territory (Cody 1996) of about 300 kilometers southeast of a site adjacent to the junction of the Campbell Highway and Nahanni Road.

Saxifraga serpyllifolia Pursh, Thyme-leaved Saxifrage — YUKON: steep northeast-facing slope, Bonnet Plume River, 65°01′03″N 134°18′03″W, *V. Loewen 99-21-74*, 14 July 1999 (DAO); moderately steep talus slope, Bonnet Plume River, 64°44′37″N 133°24′30″W, *V. Loewen 99-38-131*, 16 July 1999 (DAO).

The specimens cited above are the easternmost yet found in the Territory between latitudes 62°N and 67°N (Cody 1996).

ROSACEAE

Amelanchier alnifolia (Nutt.) Nutt., Saskatoon — YUKON: dry steep slope below cliffs above coal mine shaft, Tantalus Butte, Carmacks, 62°07.23′N 136°15.23′W, *B. Bennett 00-050*, 30 May 2000 (DAO).

The specimen cited above is intermediate between sites mapped by Cody (1996) adjacent to the southern Klondike Highway and Mayo.

Geum aleppicum Jacq. ssp. *strictum* (Ait.) Clausen, Yellow Avens — YUKON: Koidern River, 61°51′19.6″N 140°09′11.2″W, *Cody & Cody 37125*, 26 July 2000 (DAO); gravel beside Alaska Highway, Beaver Creek Community, 62°23′11.1″N 140°52′28.3″W, *Cody & Cody 37225*, 26 July 2000 (DAO).

Douglas et al. (1981) considered this species rare in the Territory. The specimens cited above extend the known range in the Territory about 175 kilometers adjacent to the Alaska Highway northwest from a site adjacent to southern Kluane Lake.

Geum macrophyllum Willd. ssp. *perincisum* (Rydb.) Hultén, Large-leaved Avens — YUKON: edge of river in older *Salix alaxensis/S. pseudomontisola/S. pulchra/Calamagrostis canadensis* meadow, Peel River Camp #10, 65°57.61′N 134°25.68′W, *B. Bennett 00-706*, 12 July 2000 (DAO).

The specimen cited above is an extension of the known range in the Territory (Cody 1996) of about 190 kilometers northeast of a site adjacent to the Dempster Highway. This species was not observed adjacent to the Wind River and the site above was the only place where it was seen on the Peel River.

Potentilla anserina L., Common Silverweed — YUKON: gravel roadside and ditch, Alaska Highway, 1.5 km north of Beaver Creek bridge, 62°22′36.3″N 140°52′35.6″W, *Cody & Cody 37192*, 26 July 2000 (DAO).

The specimen cited above is an extension of the known range in the Territory (Cody 1996) of about 180 kilometers to the northwest from a site near the south end of Kluane Lake.

Potentilla litoralis Rydb., Prairie Cinquefoil – YUKON: gravel slope, Alaska Highway just east of the Alaska border line, 62°36′52.8″N 140°59′59.8″W, *Cody & Cody 37213*, 26 July 2000 (DAO).

The specimen cited above is an extension of the known range in the Territory (Cody 1996) of about 75 kilometers to the northwest from a site south of latitude 62°N adjacent to the Alaska Highway.

Potentilla norvegica L., Norwegian Cinquefoil — YUKON: gravel slope, Alaska Highway, just east of Alaska border line, 62°36′52.8″N 140°59′59.8″W, *Cody & Cody 37204*, 26 July 2000 (DAO).

The specimen cited above is an extension of the known range in the Territory (Cody 1996) of about 60 kilometers to the northwest from a site south of latitude 62°N.

Potentilla palustris (L.) Scop., Marsh Cinquefoil — YUKON: riverbar, Wind River, 65°12.49′N 135°13.17′W, *B. Bennett 00-366*, 5 July 2000 (DAO).

The specimen cited above is from the only known locali-

ty between latitudes 64°N and 66°N, east of the Dempster Highway (Cody 1996).

Rubus arcticus L. ssp. *acaulis* (Michx.) Focke, Nagoonberry — YUKON: in hummocky *Picea/Salix* forest near river, McClusky Lake, Wind River, 64°34.19′N 134°25.77′W, *B. Bennett 00-351*, 2 July 2000 (DAO); *Larix laricina/Picea mariana/Sphagnam* marsh, Peel River, Camp #10, between Snake and Bonnet Plume rivers, 65°57.61′N 134°25.68′W, *B. Bennett 00-697*, 12 July 2000 (DAO); in rich moist herbaceous meadow adjacent to fork of Dog Creek, 68°29.14′N 138°50.35′W, *B. Bennett 00-1107*, 6 Aug. 2000 (DAO).

The first two specimens cited above are an extension of the known range in the Territory (Cody 1996) between latitudes 64°N and 66°N east of the Dempster Highway. The third specimen is the northernmost yet found in the Territory, a range extension of about 60 kilometers northeast of a site just north of latitude 68°N.

Rubus idaeus L. s.l., Wild Red Raspberry — YUKON: riparian forest in talus below cliff, Wind River, 65°12.49′N 135°13.17′W, *B. Bennett 00-134*; 5 July 2000 (DAO); riverbar near more established willows, Peel River Camp #8, 65°56.03′N 134°58.84′W, *B. Bennett 00-775*, 9 July 2000 (DAO); Richardson Mts., 66°44′51″N 135°24′40″W, *G. Brunner 24A-00*, July 2000 (Yukon Renewable Resources, photo DAO).

The specimens cited above extend the known distribution in the Territory (Cody 1996) about 150 kilometers east of the Dempster Highway.

Sanguisorba officinalis L., Great Burnet — YUKON: on open well washed riverbar, only five plants seen and two others at site downstream, Peel River, 65°55.97′N 135°02.99′W, *B. Bennett 00-381*, 9 July 2000 (DAO).

Douglas et al. (1981) considered this species rare in the Territory. The specimen cited above is an extension of the known range in the Territory (Cody 1996) of about 150 kilometers northeast of a site adjacent to the Dempster Highway reported by Cody et al. (1998).

Spiraea beauverdiana Schneid., Steven's Meadowsweet — YUKON: boggy area with hummocks, Peel River, 66°00.36′N 134°43.19′W, *B. Bennett 00-469*, 11 July 2000 (B. Bennett Herbarium, photo DAO).

The specimen cited above is an extension of the known range in the Territory (Cody 1996) of about 50 kilometers east of a site west of longitude 135°W. To the south the nearest site is adjacent to the upper Bonnet Plume River.

FABACEAE (LEGUMINOSAE)

Astragalus alpinus L., Alpine Milk-vetch — YUKON: riverbar, Wind River Camp #1, 64°40.39′N 134°35.96′W, *B. Bennett 00-358*, 2 July 2000 (DAO); open riverbar in gravels, Wind River confluence with Illytd Creek, 65°30.7′N 135°22.88′W, *B. Bennett 00-438*, 6 July 2000 (DAO).

The specimens cited above are the only records from between latitudes 64°N and 66°N and between longitude 131°30′W and the Dempster Highway (Cody 1996).

Astragalus australis (L.) Lam., Indian Milk-vetch — YUKON: riverbar with shrubby *Salix*, Wind River Outfitter's Camp, 64°34.43′N 134°88′W, *B. Bennett 00-479*, 2 July 2000 (DAO); steep active solifluxion slope, Wind River Camp #1, 64°40.39′N 134°35.96′W, *B. Bennett 00-178*, 3 July 2000 (DAO).

The specimens cited above are an extension of the known range in the Territory (Cody 1996) of about 180 kilometers east of sites adjacent to the Dempster Highway.

Astragalus bodinii Sheldon, Bodin's Milk-vetch — YUKON: uncommon in gravels of creek beds, Dog Creek Camp, Vuntut National Park, 68°27.53′N 138°44′47″W, *B. Bennett 00-547*, 8 Aug. 2000 (DAO).

The specimen cited above is an extension of the known range in the Territory (Cody 1996) of about 200 kilometers northwest of a site at about 67°N.

Astragalus williamsii Rydb., William's Milk-vetch — YUKON: clear area adjacent to highway, Alaska Highway 4.0 km S of White River bridge, 61°58′56.3″N 140°28′36.0″W, *Cody & Cody 37230*, 27 July 2000 (DAO).

The specimen cited above is an extension of about 100 kilometers northwest of a site at the north end of Kluane Lake (Cody 1996).

Melilotus alba Desc., White Sweet-clover — YUKON: in the year 2000 this Sweet-clover was found to be widely distributed along the Alaska Highway between Johnson's Crossing and the Alaska border (13 specimens in DAO); gravel roadside, 14 km S of Jakes Corner, 60°19′05.4″N 134°10′08.6″W, *Cody & Cody 37388*, 30 July 2000 (DAO); gravel clearing, Haines Highway Km 195.5, Dezadeash Lake Campground entrance, 60°23′52.9″N 137°02′51.3″W, *Cody & Cody 37265*, 28 July 2000 (DAO); dense stand along roadside, Faro, Douglass Drive off Lorna Blvd., 62°13′37.3″N 133°20′19.2″W, *Cody & Cody 36981*, 20 July 2000 (DAO); gravel at edge of road, Dempster Highway Km 1, 63°59′20.9″N 138°43′34″W, *Cody & Cody 37018*, 21 July 2000 (DAO); roadside gravel, Dempster Highway 4 km S of Benson Creek, 64°12′42.2″N 138°33′39.0″W, *Cody & Cody 37024*, 22 July 2000 (DAO).

Cody et al. (1998, 2001) reported extensions of this widespread roadside species. The specimens cited above show a tremendous extension of this species in the southern half of the Territory in the year 2000.

Melilotus officinalis (L.) Lam., Yellow Sweet-clover — YUKON: gravel clearing, Haines Highway Km 195.5, 60°23′50.9″N 137°02′51.3″W, *Cody & Cody 37266*, 28 July 2000 (DAO); roadside ditch, Robert Campbell Highway Km 477, 62°11′50.9″N 134°32′45.1″W, *Cody & Cody 36985*, 20 July 2000 (DAO); roadside gravel, Alaska Highway Km 1414.5, 60°28′18.1″N 134°15′43.6″W, *Cody & Cody 37385*, 30 July 2000 (DAO); roadside gravel, Alaska Highway, 60°48′38.2″N 135°13′31.2″W, *Cody &*

Cody 37377, 29 July 2000 (DAO); disturbed gravel roadside, Alaska Highway, 77 km W of Klondike Highway junction, 60°47′30.4″N 136°29′45.2″W, *Cody & Cody 37055*, 24 July 2000 (DAO); gravel roadside, Alaska Highway Km 1590, 60°45′49.1″N 136°49′56.4″W, *Cody & Cody 37373*, 29 July 2000 (DAO); disturbed gravel by road, Alaska Highway, 1 km E of Haines Junction, 60°46′20.2″N 137°31′05.3″W, *Cody & Cody 37061*, 25 July 2000 (DAO); broad gravel roadside, Alaska Highway 400 m NW of White Creek bridge, 61°59′27.4″N 140°33′55.6″W, *Cody & Cody 37150*, 26 July 2000 (DAO); gravel beside highway, Alaska Highway 4.9 km SE of border crossing, 62°34′46.1″N 140°57′20.9″W, *Cody & Cody 37220*, 26 July 2000 (DAO).

Although not nearly as common in the southern half of the Territory as *M. alba*, this yellow flowered species has also become widely distributed along the highways in the year 2000.

Onobrynchis viciifolia Scop., Sainfoin — YUKON: height about 1 m in dense clump, roadside, Alaska Highway Km 1463, 7 km E of Robert Service Exit, Whitehorse, 60°37′59.4″N 134°59′52.3″W, *Cody & Cody 37421*, 31 July 2000 (DAO); Whitehorse, Kelley's Canyon, Km 1440 Alaska Highway, 60°34.73′N 134°36.58′W, *B. Bennett 00-876*, 10 Sept. 2000 (DAO).

In 1980 Cody and Ginns collected this introduced species adjacent to the Alaska Highway in the vicinity of Whitehorse. The specimens cited above confirm its occurrence in the region. It was also noted eastward along the highway.

Oxytropis campestris (L.) DC. ssp. *varians* (Rydb.) Cody, Field Locoweed — YUKON: common on riverbars, Wind River Camp #1, 64°40.39′N 134°35.96′W, *B. Bennett 00-747*, 2 July 2000 (B. Bennett Herbarium, photo DAO).

The specimen cited above is an extension of the known range in the Territory (Cody 1996) of about 140 kilometers south of sites adjacent to the Peel River.

Trifolium hybridum L., Alsike Clover — YUKON: roadside gravel, 24.5 road kilometers S of Carcross at Yukon/BC border, 60°00′00.6″N 134°39′47″W, *Cody & Cody 37404*, 30 July 2000 (DAO); roadside gravel, 17 km S of Jakes Corner, 64°19′42.1″N 134°11′45.9″W, *Cody & Cody 37392*, 30 July 2000 (DAO); disturbed gravel beside road, 103 km S of Carmacks on Klondike Highway, 61°15′33.4″N 135°28′45.5″W, *Cody & Cody 37051*, 24 July 2000 (DAO); gravel roadside, Top of the World Highway Km 2.6, 64°04′21.2″N 139°27′54.4″W, *Cody & Cody 37029*, 22 July 2000 (DAO); cleared gravel area, Top of the World Highway Km 56, 64°13′49.3″N 140°16′30.9″W, *Cody & Cody 37042*, 22 July 2000 (DAO); gravel roadside, Alaska Highway 21 km NW of Lake Creek Campsite, 61°58′33.8″N 140°27′50.3″W, *Cody & Cody 37141*, 26 July 2000 (DAO); broad gravel roadside, Alaska Highway 400 m NW of White River bridge, 61°59′27.4″N 140°33′55.6″W, *Cody & Cody 37146* (DAO); disturbed gravel at road stop, Alaska Highway 7.4 km NW of Snag Junction campground, 62°17′16.4″N 140°46′45.5″W, *Cody & Cody 37178*, 26 July 2000 (DAO); gravel roadside and ditch, Alaska Highway, 1.5 km N of Beaver Creek bridge, 62°22′36.2″N 140°52′35.6″W, 26 July 2000 (DAO); slope below rest area, Alaska Highway, 18 km SE of border crossing, 62°29′57.9″N 140°51.48.4″W, 26 July 2000 (DAO); gravel slope, Alaska Highway just east of border line, 62°36′52.8″N 140°59′59.8″W, *Cody & Cody 37202*, 26 July 2000 (DAO).

The specimens of this introduced species cited above extend the known distribution in the Territory (Cody 1996) to the Alaska border adjacent to the Alaska Highway, in the extreme south, and adjacent to the Top of the World Highway.

Trifolium pratense L., Red Clover — YUKON: roadside gravel, Haines Highway Km 179, 60°15′55.4″N 136°58′30.4″W, *Cody & Cody 37260*, 28 July 2000 (DAO); disturbed gravel by roadside, Haines Highway Km 222, 100 m S of bridge over Kathleen River, 60°35′N 137°48.9″W, *Cody & Cody 37270*, 28 July 2000 (DAO).

Cody (1996) knew this introduced species in the Territory from only seven sites. An additional site in the extreme southeast was reported by Cody et al. (2000). It is new to the Haines Highway although it was previously known from Haines Junction.

Trifolium repens L., White Clover — YUKON: gravel roadside at rest stop, Haines Highway Km 150, 60°02′21.9″N 136°52′58.7″W, *Cody & Cody 37252*, 28 July 2000 (DAO); gravel by road stop, Haines Highway Km 173, 60°13′00.9″N 136°57′55.2″W, *Cody & Cody 37257*, 28 July 2000 (DAO).

The specimens of this introduced species cited above are an extension of the known range in the Territory (Cody 1996) of about 125 kilometers southwest from the vicinity of Whitehorse.

ELAEAGNACEAE

Elaeagnus commutata Bernh., Silverberry — YUKON: cobbly silty riverbar with *Salix alaxensis*, rare, only place seen, Peel River between Snake and Bonnet Plume rivers, 65°58.61′N 134°48.61′W, *B. Bennett 00-787*, 10 July 2000 (DAO).

This is the northernmost site yet found in the Territory (Cody 1996). It is an extension of about 115 kilometers northeast of sites adjacent to the Bonnet Plume River.

Shepherdia canadensis (L.) Nutt., Soapberry — YUKON: open *Picea glauca* forest, Wind River Camp #1, 64°34.43′N 134°28.88′W, *B. Bennett 00-227*, 2 July 2000 (DAO); common on riverbar dominated by *Salix alaxensis*, Wind River Camp #4, 65°22.89′N 135°25.1′W, *B. Bennett 00-257*, 5 July 2000 (DAO); in young *Populus balsamifera* forest on riverbar, Peel River, Taco Bar, 66°00.15′N 134°13′W, *B. Bennett 00-395*, 13 July 2000 (DAO).

The specimens cited above are extensions of the range in

the Territory (Cody 1996) of about 175 kilometers to the south and 60 kilometers to the east of a site adjacent to latitude 66°N.

APIACEAE (UMBELLIFERAE)

Sium suave Walt., Water-parsnip — YUKON: lakeshore bordered by *Picea glauca*, Tatchun/Frenchman Rd. Km 40, Tatchun Lake Campground, 62°16′50.0″N 136°02′09.3″W, *Cody & Cody 37007*, 21 July 2000 (DAO); wet shore of Gravel Lake, Klondike Highway Km 626, 63°48′26.5″N 137°53′56.7″W, *Cody & Cody 37012* (DAO); Horseshoe Slough, 63°26′N 135°02′W, *D. Mossop s.n.*, 13 July 2000 (B. Bennett Herbarium, photo DAO); Eagle Plains/Peel area, 66°24′N 136°58′W, *L. Schroeder 17*, 26 July 1994 (DAO).

Douglas et al. (1981) considered this species rare in the Territory. The nearest site to the first three specimens cited above is adjacent to the Nordenskiold River below Montague Mtn. (Cody et al. 2000). The fourth specimen cited above is the northernmost yet found in the Territory (Cody 1996). It is an extension north of the known range of about 300 kilometers from a site near the junction of the Klondike and Dempster highways.

CORNACEAE

Cornus canadensis L., Bunchberry — YUKON: riparian *Picea glauca/Populus balsamifera* feathermoss forest, Peel River between Snake and Bonnet Plume rivers, 65°57.61′N 134°25.68″W, *B. Bennett 00-703*, 12 July 2000 (DAO); riparian *Picea glauca/Populus balsamifera* forest with thick moss cover, Peel River, 66°00.36′N 134°43.19′W, *B. Bennett 00-463*, 11 July 2000 (DAO).

This species was not seen on the Wind River or farther upstream on the Peel River. The specimens cited above are the northernmost yet found in the Territory (Cody 1996). They are from sites about 300 kilometers north of a site just south of latitude 64°N.

Cornus stolonifera Michx., Red-osier Dogwood — YUKON: *Salix alaxensis/Alnus incana/Rosa acicularis/Shepherdia canadensis/Dryas drummondiana* gravelly riverbar, Wind River Camp #6, 65°40.46′N 135°11.76′W, *B. Bennett 00-848*, 7 July 2000 (DAO); along riverbars under *Salix alaxensis* and *Alnus incana* thickets, confluence of Wind and Peel rivers, 65°50.48′N 135°18.25′W, *B. Bennett 00-111*, 9 July 2000 (DAO); moist *Picea glauca/Alnus* thicket, riparian seeps, Peel River Site #1, 65°58.06′N 134°49.69′W, *B. Bennett 00-432*, 10 July 2000 (DAO); in young *Populus balsamifera* forest on riverbar, Peel River, Taco Bar, 60°00.15′N 134°13′W, *B. Bennett 00-379*, 13 July 2000 (DAO).

The specimens cited above are near sites adjacent to the lower Bonnet Plume River (Cody et al. 2000) including the northernmost yet found in the Territory (Cody 1996) collected about 50 kilometers to the northeast.

PYROLACEAE

Moneses uniflora (L.) Gray, One-flowered Pyrola — YUKON: older *Picea glauca/Populus balsamifera* forest beside creek in shady mossy area, Wind River Site #1, 64°40.39′N 134°35.96′W, *B. Bennett 00-743*, 2 July 2000 (DAO); growing in moss on river bank, Snake River, 64°47′N 132°40′W, *J. Meikle 99-037*, 18 July 1999 (Yukon Renewable Resources, photo DAO); steep slope with *Populus tremuloides*, Wind River, Deception Mtn., 65°36.03′N 135°28.51′W, *B. Bennett 00-443*, 7 July 2000 (DAO); riparian *Picea glauca/Populus balsamifera* feathermoss forest, Peel River between Snake and Bonnet Plume rivers, 65°57.68′N 134°25.68′W, *B. Bennett 00-702*, 12 July 2000 (DAO).

The specimens cited above from between latitude 64°and 66°N are intermediate between sites mapped by Cody (1996) adjacent to the Dempster Highway and the upper Bonnet Plume River.

Orthilia secunda (L.) House, One-sided Wintergreen — YUKON: in young *Populus balsamifera* forest on riverbar, Peel River, Taco Bar, 66°00.15′N 134°13′W, *B. Bennett 00-394*, 13 July 2000 (DAO); riparian *Picea glauca/Populus balsamifera/Alnus incana* forest, Wind River, Deception Mountain, 65°36.03′N 135°28.41′W, *B. Bennett 00-416*, 7 July 2000 (DAO); tussock tundra, Wind River Camp #2, 64°51.83′N 134°38.85′W, *B. Bennett 00-829*, 4 July 2000 (DAO); older *Picea glauca/Populus balsamifera* forest beside creek in shady mossy area, Wind River, 64°40.39′N 134°35.96′W, *B. Bennett 00-745*, 2 July 2000 (DAO).

The specimens cited above are from between sites north of 66°N and the upper part of the Bonnet Plume River (Cody 1996).

Pyrola asarifolia Michx., Pink-flowered Wintergreen — YUKON: older *Picea glauca/Populus balsamifera* forest beside creek in mossy shady area, 64°40.39′N 134°35.96′W, *B. Bennett 00-720*, 2 July 2000 (DAO); riverbar, Wind River Camp #6, 65°40.46′N 135°11.76′W, *B. Bennett 00-146*, 7 July 2000 (DAO); moist *Picea glauca/Alnus* thicket riparian with seeps, Peel River Site #1, 65°58.06′N 134°49.69′W, *B. Bennett 00-401*, 10 July 2000 (DAO); in young *Populus balsamifera* riparian forest on riverbar, Peel River, Taco Bar, 66°00.15′N 134°13′W, *B. Bennett 00-392*, 13 July 2000 (DAO).

The specimens cited above are an extension of the known range in the Territory (Cody 1996) of about 175 kilometers east of the Dempster Highway between latitudes 64°N and 67°N.

Pyrola chlorantha Sw., Greenish Wintergreen — YUKON: riparian *Picea glauca/Populus balsamifera/Alnus incana* forest, Wind River, Deception Mountain, 65°36.03′N 135°28.41′W, *B. Bennett 00-421*, 7 July 2000 (B. Bennett Herbarium, photo DAO); riparian *Picea glauca/Populus balsamifera* forest with thick moss cover, Peel River, 66°00.36′N 134°43.19′W, *B. Bennett 00-468*, 11 July 2000 (DAO); wet moss under spruce, Alaska Highway, 2.3 km SE of border crossing, 62°36′05.2″N 140°58′04.9″W, *Cody & Cody 37215*, 26 July 2000 (DAO).

The specimens cited above are an extension of the known range in the Territory (Cody 1996) of about 75 kilometers east of sites just north of latitude 66°N and of about 200 kilometers northwest of a site near the south end of Kluane Lake.

Pyrola grandiflora Radius, Arctic Wintergreen — Yukon: steep northwest-facing slope of lower cirque basin, Bonnet Plume River, 64°51′19″N 133°27′53″W, *V. Loewen 99-6-26*, 11 July 1999 (DAO); in moist White Spruce spruce forest with moss understory, Snake River, *J. Meikle* 99-038, 19 July 1999 (Yukon Renewable Resources, photo DAO).

The specimens cited above extend the known range in the Territory (Cody 1996) about 75 kilometers north of a site in the upper Bonnet Plume River.

ERICACEAE

Arctostaphylos rubra (Rehd. & Wils.) Fern., Red Alpine Bearberry — YUKON: open gravelly riverbar, Wind River, 64°40.39′N 134°35.96′W, *B. Bennett 00-180*, 3 July 2000 (DAO); hummocky *Picea mariana* site south of recent fire west of cat trail, Wind River, 64°58.67′N 134°47.12′W, *B. Bennett 00-298*, 4 July 2000 (DAO); moderately steep east-facing subalpine slope, Bonnet Plume River east of Fairchild Lake, 64°58′03″N 133°41′12″W, *V. Loewen 99-4-14*, 11 July 1999 (DAO); convex mid-slope, rock/ soil/*Dryas* ridge, Upper Bonnet Plume River Drainage Site #128, *J. Staniforth 00-107*, 8 July 2000 (DAO).

The specimens cited above extend the known range in the Territory (Cody 1996) about 200 kilometers east of sites adjacent to the Hart River.

Arctostaphylos uva-ursi (L.) Spreng., Common Bearberry — YUKON: on steep vegetated slope above river, Wind River, 64°40.39′N 134°35.96′W, *B. Bennett 00-737*, 2 July 2000 (DAO).

The specimen cited above is an extension of the known range in the Territory (Cody 1996) of about 150 kilometers east of a site between the Blackstone and Hart rivers.

Chamaedaphne calyculata (L.) Moench., Leatherleaf — YUKON: riverbar, Peel River, 65°56.03′N 134°58.84′W, *B. Bennett 00-780*, 9 July 2000 (DAO).

The specimen cited above is an extension of the known range in the Territory (Cody 1996) of about 50 kilometers northeast of a site between the Hart and Wind rivers.

Ledum groenlandicum Oeder, Labrador-tea — YUKON: in hummocky *Picea/Salix* forest near river, Wind River, McClusky Lake, 64°34.19′N 134°25.77′W, *B. Bennett 00-377*, 2 July 2000 (DAO).

The specimen cited above is intermediate between sites mapped by Cody (1996) adjacent to the Hart River and the upper Bonnet Plume River.

Oxycoccus microcarpus Turcz., Bog Cranberry — YUKON: boggy area with open pools, *Larix laricina/ Rubus chamaemorus/Ledum groenlandicum/Betula papyrifera*, Peel River, 66°00.36′N 134°43.19′W, *B. Bennett 00-465*, 11 July 2000 (DAO); fen ingrowing with *Carex limosa* and *Sphagnum* with *Andromeda*, Vuntut National Park, *B. Bennett 00-560*, 1 Aug. 2000 (DAO).

The specimen first cited above is an extension of the known range in the Territory of about 55 kilometers east of sites mapped by Cody (1996) from just north of latitude 66°N; the second specimen, from north of 68°N, is notable since there are only two other sites north of this latitude.

PRIMULACEAE

Androsace chamaejasme Host. ssp. *lehmanniana* (Spreng.) Hultén, Rock-jasmine — YUKON: south-west-facing slope, small carbonate face, Snake River, 65°06.5′N 133°07′W, *J. Meikle 99-041A*, 19 July 1999 (Yukon Renewable Resources, photo DAO).

The specimen cited above is an extension of the known range in the Territory (Cody 1996) of about 50 kilometers east of a site adjacent to the Bonnet Plume River.

Primula mistassinica Michx., Bird′s-eye Primrose — YUKON: riverbar, Wind River, 64°34.43′N 134°28.88′W, *B. Bennett 00-211*, 2 July 2000 (DAO); riverbar, Wind River Camp #1, 64°40.39′N 134°35.96′W, *B. Bennett 00-356*, 2 July 2000, (DAO); in moss on riverbank, Wind River Camp #5, 65°35.38′N 135°27.6′W, *B. Bennett 00-141*, 6 July 2000 (DAO); common on turfy sites by creek in woods below timberline, Upper Big Creek, Dawson Range, 62°18′N 137°53′W, *R. Frisch s.n.*, 7 June 1982 (DAO).

Douglas et al. (1981) considered this species rare in the Territory. The first three specimens cited above are the northernmost yet known in the Territory (Cody 1996). They are an extension of the known range of about 225 kilometers northwest from a site adjacent to the upper Bonnet Plume River. The fourth specimen is an extension of the known range of about 80 kilometers east of a site west of longitude 139°W.

PLUMBAGINACEAE

Armeria maritima (Mill.) Willd. ssp. *arctica* (Cham.) Hultén, Sea Thrift — YUKON: boggy tussock tundra near small pond, uncommon in this area but several groups seen throughout and onto riverbars, Wind River Camp #2, 64°51.83′N 134°38.85′W, *B. Bennett 00-818*, 4 July 2000 (DAO); base of talus slope in calcareous outwash, Wind River Camp #3 east bank near confluence of Royal Creek, 65°06.83′N 134°47.12′W, *B. Bennett 00-216*, 4 July 2000 (B. Bennett Herbarium, photo DAO).

The specimen cited above is an extension of the known range in the Territory (Cody 1996) of about 575 kilometers south of the Arctic coast and British Mountains. It is however known in the Mackenzie Mountains to the east.

MENYANTHACEAE

Menyanthes trifoliata L., Buckbean — YUKON: Sam Lake, Vuntut National Park, 68°24.24′N 138°37.58′W, *B. Bennett 00-552*, 5 Aug. 2000 (DAO).

The specimen cited above is an extension of the known range in the Territory (Cody 1996) of about 50 kilometers northeast of the only other collection from north of latitude 68°N.

POLEMONIACEAE

Phlox alaskensis Jordal, Alaskan Phlox — YUKON: in steep loose talus, west-facing slope, Wind River Camp #3, 65°06.83′N 134°37.12′W, *B. Bennett 00-157, 00-217*, 4 July 2000 (DAO).

The specimens cited above are an extension of the known range in the Territory (Cody 1996) of about 80 kilometers east of a site east of Hart River.

Polemonium boreale Adams, Northern Jacob's-ladder – YUKON: gravel beside Alaska Highway, Beaver Creek Community, 62°23′11.1″N 140°52′28.3″W, *Cody & Cody 37227* (DAO).

The nearest site of this species adjacent to the Alaska Highway to the specimen cited above is about 140 kilometers to the southeast near the north end of Kluane Lake (Cody 1996). It is however known from adjacent to the Alaska border at about latitude 62°N.

BORAGINACEAE

Mertensia paniculata (Ait.) G. Don var. *paniculata*, Bluebell — YUKON: borders of roads in campground by *Salix*, *Alnus* and *Picea*, Pine Valley Campground, Alaska Highway, 61°51′14.3″N 140°08′58.9″W, *Cody & Cody 37114*, 26 July 2000 (DAO); gravel beside Alaska Highway, Beaver Creek Community, 62°23′11.1″N 140°52′28.3″W, *Cody & Cody 37226* (DAO).

The specimens cited above are an extension of the known range in the Territory (Cody 1996) of about 180 kilometers northwest of a site adjacent to the south end of Kluane Lake.

LAMIACEAE (LABIATAE)

Scutellaria galericulata L. var. *pubescens* Benth., Narrow-leaved Skullcap — YUKON: wet shore of Gravel Lake, Klondike Highway Km 626, 63°48′26.5″N 137°53′56.7″W, *Cody & Cody 37010*, 21 July 2000 (DAO).

The specimen cited above is an extension of the known range in the Territory of about 100 kilometers to the west from the vicinity of Mayo (Cody 1996). Douglas et al. (1981) considered this species rare in the Territory.

SCROPHULARIACEAE

Pedicularis capitata Adams, Capitate Lousewort — YUKON: lower South Bend on Snake River, 65°06′N 133°06′W, *J. Meikle 99-045*, 19 July 1999 (Yukon Renewable Resources, photo DAO).

The specimen cited above is an extension of the known range in the Territory (Cody 1996) of about 50 kilometers northeast of a site between the Wind and Bonnet Plume rivers.

Pedicularis langsdorfii Fisch. ssp. *arctica* (R.Br.) Pennell ex Hultén, Langdorf's Lousewort — YUKON: riverbar, shrubby *Salix*, occasional, Wind River Outfitter's Camp #1, 64°34.43′N 134°28.88′W, *B. Bennett 00-266*, 2 July 2000 (DAO); open dolomite delta, Wind River, 64°48.46′N 134°41.34′W, *B. Bennett 00-319*, 3 July 2000 (DAO).

The specimens cited above are an extension of the known range in the Territory (Cody 1996) of about 80 kilometers north of a site just north of latitude 64°N.

Pedicularis verticillata L., Whorled Lousewort — YUKON: riverbar, Wind River, 64°34.43′N 134°28.88′W, *B. Bennett 00-269*, 2 July 2000 (DAO); common on riverbar dominated by *Salix alaxensis*, Wind River Camp #1, 64°40.39′N 134°35.96′W, *B. Bennett 00-249*, 3 July 2000 (DAO).

The specimens cited above are intermediate between sites west of the Hart River mapped by Cody (1996) and a site adjacent to the Snake River (Cody et al. 2001).

LENTIBULARIACEAE

Utricularia vulgaris L. ssp. *macrorhiza* (Le Conte) Clausen, Greater Bladderwort — YUKON: in shallows of small upland lake, Frances Lake, 61°11′N 129°08′W, *R. Rosie 2007*, 5 June 1998 (DAO), *R. Rosie 2008*, 17 Oct. 1999 (DAO).

The specimens cited above are intermediate between sites adjacent to the Canol Road (Cody 1996) and a site adjacent to the Beaver River (Cody et al. 2000).

PLANTAGINACEAE

Plantago eriopoda Torr., Saline Plantain — YUKON: rare along roadside, Klondike Highway 81 km S of Stewart Crossing, 62°44′52.6″N 136°39′32.4″W, *Cody & Cody 37046*, 24 July 2000 (DAO).

The specimen cited above is an extension of the known range in the Territory (Cody 1996) of about 100 kilometers north of sites adjacent to the highway south of Carmacks.

Plantago major L., Common Plantain — YUKON: disturbed gravel by boat ramp, North Canol Road Km 333 at Dragon Lake, 62°33′19.6″N 131°20′26.8″W, *Cody & Cody 36947*, 19 July 2000 (DAO); gravel cleared area, Faro, 62°13′59.2″N 133°20′57.3″W, *Cody & Cody 36967*, 20 July 2000 (DAO); gravel by roadside stop, Little Salmon River, Campbell Highway Km 553, 62°05′N 135°30′W, *Cody & Cody 35807*, 5 July 1999 (DAO); Koidern River (Edith Creek) behind the Pine Valley Campground, 61°51′19.6″N 140°09′11.2″W, *Cody & Cody 37123*, 26 July 2000 (DAO); gravel slope, Alaska Highway, just east of Alaska border line, 62°36′52.8″N 140°59′59.8″W, *Cody & Cody 37201*, 26 July 2000 (DAO); gravel parking area beside shrubs at Forty Mile Herd Rest Stop, Top of the World Highway Km 14, 64°05′16.5″N 139°36′49.4″W, *Cody & Cody 37032*, 22 July 2000 (DAO).

This introduced species which is widespread in the Territory (Cody 1996) was not previously known from adjacent to the Canol Road, Campbell Highway, extreme northern Alaska Highway or Top of the World Highway.

CAPRIFOLIACEAE

Linnaea borealis L. ssp. *americana* (Forbes) Hultén, Twinflower — on steep vegetated slope above river, Wind River, 64°40.39′N 134°35.96′W, *B. Bennett 00-725*, 2 July 2000 (DAO); riparian *Picea*

glauca/Populus balsamifera/Alnus incana forest, Wind River, Deception Mountain, 65°36.03′N 135°28.41′W, *B. Bennett 00-281*, 7 July 2000 (DAO); riparian *Picea glauca*, *Populus balsamifera* forest with thick moss cover, Peel River, 66°00.36′N 133°43.19′W, *B. Bennett 00-466*, 11 July 2000 (DAO).

The specimens cited above extend the known distribution in the Territory (Cody 1996) about 150 kilometers to the south and 75 kilometers east of a site between the Hart and Wind rivers.

Viburnum edule (Michx.) Raf., Low Bush-cranberry — YUKON: lush *Picea glauca/Alnus incana* established riparian thicket, Wind River Camp #4, 65°22.89′N 135°26.1′W, *B. Bennett 00-168*, 5 July 2000 (DAO); riparian *Picea glauca*, *Populus balsamifera*, *Alnus incana* forest, Deception Mountain, Wind River, 65°36.03′N 135°28.41′W, *B. Bennett 00-428*, 7 July 2000 (DAO); edge of river in older *Salix alaxensis/S. pseudomonticola/S. pulchra/Calamagrostis canadensis* meadow, 65°58.13′N 134°25.68′W, *B. Bennett 00-714*, 12 July 2000 (DAO); older riparian *Picea glauca/Populus balsamifera* forest with *Eleaganus*, Peel River Camp #9, 65°58.13′N 134°48.61′W, *B. Bennett 00-792*, 10 July 2000 (DAO); shrub-thicket on strongly mounded lower slope, Upper Bonnet Plume River Drainage near site #151, 64°30′24″N 133°01′59″W, *J. Staniforth 00-144*, 11 July 2000 (DAO).

The specimens cited above are an extension of the range in the Territory (Cody 1996) of about 250 kilometers north and 100 kilometers northeast from sites south of latitude 64°N.

CAMPANULACEAE

Campanula aurita Greene, Yukon Bellflower — in calcareous talus, Peel River Site #1, 65°58.06′N 134°49.69′W, *B. Bennett 00-407*, 10 July 2000 (B. Bennett Herbarium, photo DAO); riverbar, base of cliff, Wind River, 65°12.49′N 135°13.17′W, *B. Bennett 00-365*, 5 July 2000 (B. Bennett Herbarium, photo DAO); calcareous scree, Wind River, 64°51.83′N 134°38.85′W, *B. Bennett 00-822*, 4 July 2000 (DAO); open dolomite area, Wind River, 64°48.46′N 134°41.46′W, *B. Bennett 00-317*, 3 July 2000 (DAO).

The specimens cited above extend the known range in the Territory (Cody 1996) about 165 kilometers to the south from a site north of latitude 66°N.

Campanula uniflora L., Arctic Harebell — YUKON: moist seepage area, Bonnet Plume River, 64°53′27″N 133°48′01″W, *V. Loewen 99-19-73*, 13 July 1999 (DAO).

The specimen cited above is an extension of the known range in the Territory (Cody 1996) of about 185 kilometers east of a site west of Hart River.

ASTERACEAE (COMPOSITAE)

Achillea millefolium L. ssp. *lanulosa* (Nutt.) Piper, Common Yarrow — YUKON: roadside gravel, Burwash Landing, Alaska Highway, 61°21′17.5″N 139°00′04.6″W, *Cody & Cody 37094*, 25 July 2000 (DAO); borders of roads in campground by *Salix*, *Alnus* and *Picea*, Pine Valley Campground, Alaska Highway, 61°51′14.3″N 140°08′58.9″W, *Cody & Cody 37107*, 26 July 2000 (DAO); open riverbar, recently flooded, Peel River, 65°55.97′N 135°03′W, *B. Bennett 00-103*, 9 July 2000 (B. Bennett Herbarium, photo DAO).

Douglas et al. (1981) considered this species rare in the Territory. Cody (1996) knew it from nine sites north to latitude 64°N. The first specimens cited above extend the known range in the Territory about 290 kilometers northwest of Whitehorse. The last specimen that is the northernmost yet found in the Territory is an extension of the known range to the north of about 230 kilometers from a site in the vicinity of Mayo.

Achillea sibirica Ledeb., Siberian Yarrow — YUKON: gravel slope, Alaska Highway just east of Alaska border line, 62°36′53.8″N 140°59′59.8″W, *Cody & Cody 37198*, 26 July 2000 (DAO).

The specimen cited above is an extension of the known range in the Territory (Cody 1996) of about 100 kilometers to the northwest from a site south of latitude 62°N adjacent to the Alaska Highway.

Antennaria monocephala DC. ssp. *monocephala*, Pygmy Pussytoes — YUKON: saddle in alpine upper slope of mountain east of Fairchild Lake, Bonnet Plume River, 64°58′23″N 133°42′15″W, *V. Loewen 99-1-4*, 11 July 1999 (DAO).

The specimen cited above is an extension of the known range in the Territory (Cody 1996) of about 80 kilometers east of a site west of longitude 135°W.

Antennaria pulcherrima (Hook.) Greene, Showy Pussytoes — YUKON: common on riverbar, Wind River Camp #1, 64°40.39′N 134°35.96′W, *B. Bennett 00-247*, 3 July 2000 (B. Bennett Herbarium, photo DAO).

The specimen cited above is about 100 kilometers northwest of a site adjacent to the upper Bonnet Plume River (Cody 1996) and 100 kilometers southwest of the northernmost site in the Territory (Cody et al. 2001).

Artemisia alaskana Rydb., Alaska Sagebrush — YUKON: cobbly silty riverbar with *Salix alaxensis* shrub, Peel River Camp #9 between Snake and Bonnet Plume rivers, 65°58.13′N 134°48.61′W, *B. Bennett 00-788*, 10 July 2000 (DAO).

The specimen cited above is an extension of the known range in the Territory (Cody 1996) of about 125 kilometers north of a site adjacent to the Bonnet Plume River.

Artemisia biennis Willd., Wormwood — YUKON: gravel cleared area, Faro, 62°13′59.2″N 133°20′57.3″W, *Cody & Cody 36970*, 20 July 2000 (DAO).

The specimen of this introduced species cited above is only from the third known area in the Territory. It was known to Cody (1996) only from the vicinity of the Porcupine River and Cody et al. (2000) from the extreme southeast.

Artemisia campestris L. s.l., Northern Wormwood — YUKON: riverbar, Wind River, 64°44.64′N 134°38.3′W, *B. Bennett 00-181*, 3 July 2000 (DAO); gravelly riverbar, Wind River, 65°35.38′N 135°27.6′W, *B. Bennett 00-140*, 6 July 2000 (DAO).

The specimens cited above are intermediate between the two northernmost sites mapped by Cody (1996) adjacent to the Bonnet Plume River and north of latitude 66°N.

Artemisia michauxiana Bess. in Hook., Michaux's Mugwort — YUKON: only plant growing in railway bed, Quartz Road, Whitehorse, 60°44.05′N 135°04.09′W, *B. Bennett 00-052*, 6 June 2000 (B. Bennett Herbarium, photo DAO); very steep loose shale, Tagish Road hill across from Crag Lake 60°15′24″N 134°29′12″W, *B. Bennett 01-016*, 19 May 2001 (B. Bennett Herbarium, photo DAO).

This species was considered rare in the Territory (Douglas et al. 1981) on the basis of a collection from the vicinity of Johnsons Crossing; Cody et al. (2001) reported a second collection from a sand beach at Carcross; the first specimen cited above is the northernmost yet found in the Territory; the second specimen cited above, which is only from the fourth site known in the .Territory is from a site northeast of Carcross.

Artemisia tilesii Ledeb. s.l., Aleutian Mugwort — YUKON: in talus below cliff, Wind River, 65°12.49′N 135°13.17′W, *B. Bennett 00-135*, 5 July 2000 (DAO).

The specimen cited above is between sites mapped by Cody (1996) from the Hart River and Dempster Highway and a site adjacent to the Snake River (Cody et al. 2001).

Aster sibiricus L., Arctic Aster — YUKON: semi-active flood plain on gravelly soil in back-channel, Snake River, 64°45.57′N 132°35.81′W, *J. Meikle 99-051*, 18 July 1999 (Yukon Renewable Resources, photo DAO).

The specimen cited above is an extension of the known range in the Territory (Cody 1996) of about 75 kilometers northwest of a site adjacent to the upper Bonnet Plume River.

Crepis nana Richards., Dwarf Hawksbeard — YUKON: roadside gravel slope, Alaska Highway, 20 km NW of White River bridge, 62°08′39.6″N 140°41′05.0″W, *Cody & Cody 36157*, 26 July 2000 (DAO).

The specimen cited above is an extension of the known range in the Territory of about 120 kilometers from a site near the northern end of Kluane Lake (Cody 1996).

Erigeron hyssopifolius Michx., Hyssop-leaf Fleabane — YUKON: common on riverbars, Wind River Camp #1, 64°40.39′N 134°35.96′W, *B. Bennett 00-353, 00-756*, 2 July 2000 (DAO); riverbar, Wind River Camp #4, 65°22.89′N 135°26.1′W, *B. Bennett 00-301*, 5 July 2000 (DAO); vegetated established river bank, Wind River Camp #6, 65°40.46′N 135°11.76′W, *B. Bennett 00-142*, 7 July 2000 (DAO); silty seep on edge of river, Peel River Site #1, 65°58.06′N 134°49.69′W, *B. Bennett 00-434*, 10 July 2000 (DAO).

Douglas et al. (1981) considered this species rare in the Territory in the Richardson Mts. but the approximate circle on his map was too far south. Cody (1996) knew it from four sites between latitudes 64°N and 66°N from adjacent to the Bonnet Plume River and between the Wind and Hart rivers. The specimens cited above are the first known from the Wind and Peel rivers.

Erigeron lonchophyllus Hook., Spear-leaved Fleabane — YUKON: gravelly roadside, Tatchun/Frenchman Road, 62°07′N 135°45′W, *B. Bennett 99-127*, 15 July 1999 (DAO).

The specimen cited above is intermediate between sites mapped by Cody (1996) just north of Whitehorse and in the vicinity of Mayo.

Haplopappus macleanii Brandegee, Northern Mock Goldenweed — YUKON: dry open steep hillside just east of pullout on Robert Campbell Highway, Carmacks, Eagle Rock, 62°01.75′N 135°50.62′W, *B. Bennett 00-048*, 20 May 2000 (DAO).

Douglas et al. (1981) considered this species rare in the Territory. The specimen cited above is from a site intermediate between the north end of Lake Laberge and the Klondike Highway south of Pelly Crossing (Cody 1996).

Matricaria matricarioides (Less.) Porter, Pineappleweed — YUKON: gravel roadside, Koidern River (Edith Creek) behind the Pine Valley Campground, 61°51′19.6″N 140°09′11.2″W, *Cody & Cody 37130*, 26 July 2000 (DAO); disturbed gravel at roadstop, Alaska Highway 7.4 km NW of Snag Junction Campground, 62°16′16.4″N 140°46′45.5″W, *Cody & Cody 37187A*, 26 July 2000 (DAO); disturbed camp area, Wind River Camp #2, 64°45.05′N 134°38.75′W, *B. Bennett 00-186*, 3 July 2000 (DAO).

The specimens cited above extend the known distribution of this cosmopolitan weed, which is widespread in the Territory (Cody 1996), about 75 kilometers to the northwest adjacent to the Alaska Highway near the Alaska border and to the northeast about 115 kilometers from the vicinity of Mayo.

Matricaria perforata Mérat, Scentless Mayweed — YUKON: sandy gravel cleared area, Top of the World Highway Km 32, 64°10′26.6″N 139°52′38.3″W, *Cody & Cody 37040*, 22 July 2000 (DAO).

This adventive species from Europe was only known in the Territory (Cody 1996) from the vicinities of Ross River and Frances Lake and to Cody et al. (2000) from the vicinity of Colwell Bay.

Petasites frigidus (L.) Fries ssp. *frigidus*, Sweet Coltsfoot — YUKON: moist area between cliff and *Salix/Populus/Picea* forest, Wind River Camp #4, 65°22.89′N 135°26.1′W, *B. Bennett 00-200*, 5 July 2000 (DAO); steep slope with *Populus tremuloides*, Wind River, Deception Mtn., 65°36.03′N 135°28.41′W, *B. Bennett 00-466*, 7 July 2000 (DAO); McClusky Lake, Wind River, 64°54.19′N 134°25.77′W, *B. Bennett 00-326*, 2 July 2000 (DAO).

The specimens cited above are from sites intermediate between a site adjacent to the Blackstone River (Cody 1996) and the Snake River (Cody et al. 2001).

Petasites frigidus (L.) Fries ssp. *palmatus* (Ait.) Cody — YUKON: slumping eroding banks, cobbles and silty muck, Wind River, 65°47.45′N 135°13′W, *B. Bennett 00-121*, 8 July 2000 (DAO); lush seep draining upland, Wind River, 65°14.8′N 135°18.51′W, *B. Bennett 00-130*, 5 July 2000 (DAO).

The specimens cited above are an extension of the known range in the Territory (Cody 1996) of about 500 kilometers from sites south of 61°30′N.

Senecio atropurpureus (Ledeb.) Fedtsch. ssp. *frigidus* (Richards.) Hultén, Purple-haired Groundsel — YUKON: moderately steep north-facing slope, Bonnet Plume River, 64°51′10″N 133°27′41″W, *V. Loewen 99-5-25*, 11 July 1999 (DAO); steep talus slope, Wind River Camp #4, 65°22.89′N 135°26.1″W, *B. Bennett 00-202*, 5 July 2000 (B. Bennett Herbarium, photo DAO); *Larix laricina/ Picea mariana/Sphagnum* bog, Peel River Camp #10, 65°57′N 134°25.68′W, *B. Bennett 00-708*, 12 July 2000 (B. Bennett Herbarium, photo DAO); undulating spruce/shrub/low shrub/forb/moss, Upper Bonnet Plume River Drainage Site #116, 64°26′6″N 132°15′28″W, *J. Staniforth 00-015*, 5 July 2000 (DAO); undulating upper slope, steep alpine ridge, rock rubble, bare soil and sparse vegetation, Upper Bonnet Plume River Drainage Site #125, 64°32′45″N 132°50′48″W, *J. Staniforth 00-102*, 8 July 2000 (DAO); Snake River, 65°01′N 133°07′W, *J. Meikle 99-056*, 19 July 1999 (Yukon Renewable Resources, photo DAO).

The specimens cited above are intermediate between latitudes 64° and 66° east of a site just east of longitude 137°W (Cody 1996).

Solidago canadensis L. var. *salebrosa* (Piper) Jones, Canada Goldenrod — YUKON: loose talus at base of steep shale scree slope, confluence of Peel and Wind rivers, 65°50.48′N 135°18.25′W, *B. Bennett 00-784*, 8 July 2000 (B. Bennett Herbarium, photo DAO); riverbar near slough, Peel River Camp #8, 65°56.03′N 134°58.43′W, *B. Bennett 00-777*, 9 July 2000 (DAO); cobbly silty riverbar with *Salix alaxensis* shrub, between Snake and Bonnet Plume rivers, 65°58.13′N 134°48.61′W, *B. Bennett 00-794*, 10 July 2000 (DAO).

The specimen cited above is an extension of the known range in the Territory (Cody 1996) of about 280 kilometers to the northwest from sites adjacent to the Yukon River in the vicinity of Dawson City.

Solidago simplex Kunth, Spike-like Goldenrod — YUKON: less active areas on riverbar, Wind River, 65°12.49′N 135°13.17′W, *B. Bennett 00-456*, 5 July 2000 (B. Bennett Herbarium, photo DAO); slumping eroding banks, cobbles and silty muck, Wind River, 65°47.45′N 135°13′W, *B. Bennett 00-123*, 8 July 2000 (DAO); loose talus at base of steep active shale scree slope, junction of Wind and Peel rivers, 65°50.48′N 135°18.25′W, *B. Bennett 00-783*, 8 July 2000 (DAO).

The specimens cited above are an extension of the known range in the Territory (Cody 1996) of about 200 kilometers northeast from a site adjacent to the upper Bonnet Plume River.

Taraxacum ceratophyllum (Ledeb.) DC., Horned Dandelion — YUKON: in open meadow near outfitter cabins, Wind River, McClusky Lake, 64°34.19′N 134°25.77″W, *B. Bennett 00-340*, 2 July 2000 (DAO).

The specimen cited above is an extension of the known range in the Territory (Cody 1996) of about 100 kilometers northwest of a site adjacent to the upper Bonnet Plume River.

Taraxacum officinale Weber ex Wiggers, Common Dandelion — YUKON: open meadow near outfitter's camp, Wind River, McClusky Lake, 64°34.19′N 134°25.77′W, *B. Bennett 00-235*, 2 July 2000 (DAO).

The specimen cited above is an extension of the known range in the Territory (Cody 1996) of about 90 kilometers northeast from a site in the vicinity of Mayo.

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Breeding Birds in Forestry Plantations and Natural Forest in the Vicinity of Fundy National Park, New Brunswick

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We studied the populations of breeding birds in five reference stands of natural mixedwood forest and 11 conifer plantations up to 21-years old in southern New Brunswick, Canada. Variations of the distribution and abundance of birds were related to changes in the plant-species composition and structural attributes of their habitat. Bird species occurred in plantations in levels of abundance and diversity similar to that of reference forest, although community composition was highly dissimilar. Species of reference stands were typical of mature, mixedwood forest. Species of younger plantations were typical of open, early successional, upland habitats. Once the plantations became older than 13 years and the tree height exceeded about 5 m, birds typical of conifer forest began to invade the habitat, resulting in a mixed-species composition. Although cavity-containing snags were rare in the plantations, if they did occur in them or near their edge they were used by hole-nesting birds. Although we could not study a complete rotation, the field data and habitat trajectory suggest that the plantations will not support some elements of the avian biodiversity of the natural forest in the study area. The mature plantations will be highly depauperate in coarse-woody debris, snags, and cavities, and will not support species dependent on these critical habitat elements. In addition, birds requiring habitat containing trees of larger size and of various species, including hardwoods, will not find the mature plantations to be suitable. To accommodate the needs of species potentially at risk from the extensive development of plantations, the following changes in forestry management practices should be instituted: (1) retention of natural cavity-trees, snags, coarse-woody debris, and hardwood trees and shrubs in residual non-harvested "islands" within clear-cuts and plantations; (b) retention of a patchy angiosperm component by leaving some areas untreated during herbicide applications; and (c) setting aside large areas of natural forest as non-harvested protected areas. Although we believe that these mitigations would help sustain elements of indigenous biodiversity that are at risk in an extensive industrial forest, we stress that these predictions would have to be tested through additional research and monitoring.

Key Words: Breeding birds, forestry, monitoring, plantations, Fundy National Park, New Brunswick

Numerous studies have related changes in the structure and quality of habitats in temperate forest to variations of the diversity and abundance of the birds present (Freedman et al. 1994; Hunter 1999). However, accurate predictions cannot yet be made of the effects of forest harvesting and plantation establishment on avian communities. This is due to geographical variations in bird species and communities, and in their responses to changes in habitat structure and quality caused by forestry practices.

Studies in Europe and the southern United States have found that intensively managed conifer plantations support relatively small populations of few bird species (Moss 1978; Repenning and Labisky 1985; Donald et al. 1998). A study in New Brunswick, however, found smaller effects on birds (Parker et al. 1994). Other relevant studies have examined the effects of clear-cutting and other harvesting practices on birds and their communities, including work in Nova Scotia (Freedman et al. 1981; Morgan and Freedman 1986), central Ontario (James and Peck 1995), and in the central and northeastern U.S. (Crawford and Titterington 1979; Titterington et al. 1979; Niemi and Hanowski 1984).

In this contribution we summarize the results of a study of birds breeding in conifer plantations in the vicinity of Fundy National Park (FNP), New Brunswick. We examined a chronosequence of 11 plantations up to 21 years old to describe the avian communities occurring during post-establishment succession. We also examined birds in natural, mixed-species forest of the type that has not been clear-cut and converted into the plantations, to examine consequences of the conversion for avian species, guilds, and communities.

Methods

Study Area

The study area (centered at 45.66° N and 65.10° W) is in the Greater Fundy Ecosystem (GFE) in southeastern New Brunswick. The GFE consists of Fundy National Park, a protected area of about 206 km^2, plus its nearby surrounding area, which is a mosaic of forestry plantations, clear-cuts, residual stands of natural mixedwood forest, and agricultural land. The GFE has been the locale for various studies of environmental stressors that are potential threats to the ecological integrity of the region, with a focus on the effects of forestry practices (Woodley et al. 1998*).

*See Documents Cited section

Our avian study sites are located within the Fundy Plateau Ecodistrict of the Southern Uplands Ecoregion of the Acadian Forest Region (Loucks 1962; Rowe 1972). The climax forest of the Ecodistrict is dominated by mixed-species stands containing Red and White spruce (*Picea rubens* and *P. glauca*), Balsam Fir (*Abies balsamea*), Sugar and Red maple (*Acer saccharum* and *A. rubrum*), and Yellow, White, and Mountain birch (*Betula alleghaniensis, B. papyrifera,* and *B. cordifolia*). Extensive gap-phase disturbances, largely associated with natural irruptions of Spruce Budworm (*Choristoneura fumiferana*), have resulted in most mature forest in the region having a mixed-species composition, with patches of angiosperm trees and regenerating conifers.

The landscape of the GFE has also been greatly affected by a range of anthropogenic stressors associated with forestry, agriculture, tourism, and transportation infrastructure. In particular, much of the natural forest outside of Fundy National Park has been clear-cut and converted into conifer plantations to be harvested on about a 40-year rotation. The most frequently planted species is Black Spruce (*Picea mariana*), which is less vulnerable to suffering damage from Spruce Budworm than other spruces or Balsam Fir. Some plantations are stocked with other conifers, such as Jack Pine (*Pinus banksiana*), Larch (*Larix laricina*), and Norway Spruce (*Picea abies*).

Study Sites

The five reference stands are representative of the natural, mixed-species forest that has not been harvested and converted into nearby plantations. As defined here, angiosperm-dominated reference stands (RA) have >70% hardwood basal area; mixedwood stands (RM) have 36-70%, and conifer-dominated stands (RC) have <36% (Table 1). The reference stands were in a mature condition at the time of our study, although they had been selectively logged at various times prior to the establishment of the national park in 1948, when there were sawmills in the area and small settlements for which firewood was harvested (Burzynski 1985).

The 11 plantations studied are located within 5 km of the park, and were chosen to represent the age range present when we began our study in 1993 (i.e., ranging from 3 to 21 years old). The plantations were planted to Black Spruce, except for one Larch stand. The plantations also had a vigorous natural regeneration of Balsam Fir, as well as various species of angiosperm shrubs and monocotyledonous and dicotyledonous forbs (Veinotte et al. 2002*). In all cases, the plantations had been established after the clear-cutting of natural, mature, mixed-species forest of a type similar to our reference stands. After they were clear-cut, the sites were mechanically site-prepared and then planted to conifer seedlings. The plantations received a herbicide treatment to suppress competing vegetation, intended to allow faster growth of the planted conifers.

TABLE 1. Description of the 16 study stands and sampling design. Reference stands (R) have prefix "A" if hardwood-dominated, "M" if mixed-species, and "C" if conifer-dominated; plantations are denoted by "P" plus the age since establishment.

Site	Prominent tree species (% total basal area)	Age (yr)	Area (ha)	Year Surveyed
Reference Forest				
RA1	As (26), Ba (21), Pr (17), Ar (17)	60	13.4	1992
RM1	As (35), Pr (27), Ar (18), Fg (16), Ba (4)	55	10.0	1993
RM2	Pr (59), Ba (27), Ar (8), Bc (6)	105	10.0	1993
RC1	Pr (74), Bc (11), Ar (10), Ba (3)	65	11.8	1992
RC2	Pr (67), Ba (16), Ar (13), Bc (3)	85	10.0	1993
Plantations				
P21	Pm* (86), Ab (12), Pg (1)	21	10.0	1993
P15	Pm* (78), Ab (22)	15	10.1	1992
P13	Pm* (82), Ab (13)	13	10.0	1993
P8	Pm* (61), Ab (38), Bc (2)	8	10.0	1993
P7a	No trees	7	14.1	1993
P7b	Pm* (78), Ab (22)	7	10.0	1993
P6	Ab (84), Ll* (16)	6	10.3	1993
P5a	No trees	5	10.0	1993
P5b	No trees	5	10.0	1993
P4	No trees	4	10.0	1993
P3	No trees	3	11.5	1992

Species codes: Ab = *Abies balsamea;* Ar = *Acer rubrum;* As = *Acer saccharum;* Ba = *Betula alleghaniensis;* Bc = *Betula cordifolia;* Bp = *Betula papyrifera;* Fg = *Fagus grandifolia;* Pg = *Picea glauca;* Ll = *Larix laricina;* Pm = *Picea mariana;* Pr = *Picea rubens;* * = planted stock.

All of the study sites are well-drained and located on flat terrain with gentle slopes less than about five degrees. The soil association is Lomond (Woodley 1985*), a humo-ferric podzol (Canada Soil Survey Committee 1978; Maliondo et al. 1990). All sites occur in a relatively small area, and are within 4 km of at least one other study site.

Habitat Measurements

Living and dead (i.e., snags) tree-sized stems (i.e., having a diameter at breast height (DBH) > 5 cm) in reference stands were sampled in 12 quadrats of 20 m × 20 m. Because the distribution and size spectrum of trees in plantations were relatively homogenous, they were sampled using fewer (9) quadrats of a smaller size (10 m × 10 m). Shrub-sized plants (DBH < 5 cm) were measured in two 5 m × 5 m quadrats nested in opposite corners of each tree quadrat. The length and diameter of coarse woody debris (CWD; diameter > 5 cm) were also recorded in the tree quadrats.

The ground vegetation was sampled in 30 quadrats (1 m × 1 m) placed randomly along transects running through each site. The percent cover of each plant species was visually estimated, and could exceed 100% due to layering of the foliage.

The vertical distribution of plant cover was estimated at 25 evenly spaced points per stand. Vertical cover was estimated as the average cover of foliage obscuring a 5-cm-wide, 4-m-tall pole, within each of four height intervals (0–1 m, 1–2 m, 2–3 m, and 3–4 m) when viewed at a distance of 10 m in each of the four cardinal compass directions. Overhead canopy cover was estimated by sighting upwards through a 4.2-cm diameter, 10.5-cm long cylinder, from a height of 1.75 m. The height of the overhead canopy was also estimated.

Bird Census

Breeding birds were censused at 11 plantations and five reference sites (six during the 1992 field season, and an additional 10 in 1993). All plots were at least 10 hectares in area, and the spot-mapping technique was used to census birds (International Bird Census Committee 1970). Each plot was surveyed 10 times from the last week of May to mid-July, including two evening counts. Surveys were not conducted on windy or rainy days, as these conditions interfere with audibility. Territories were assigned on the basis of clusters of observations, coupled with delineation of territorial boundaries between individual males using records of simultaneous singing (Bibby et al. 1992). Full or half-territories were designated, with a "+" designation given in cases where a smaller part of a territory occurred within a census plot (these were assigned a value of 0.2 in the data analyses; Kirk et al. 1996). The data were standardized as the number of territories per 10 hectares. Species observed more than once on a census plot, but not having sufficient observations to be assigned part of a territory (as defined by Bibby et al. 1992), were identified as visitors, or "v." Species recorded once were identified as transients, or "t."

Data Analysis

Density and species richness were determined for breeding birds and for nesting and breeding guilds, which can be useful indicators of the effects of management practices (Thingstad 1997). We examined five nesting guilds (ground, shrub canopy, tree canopy, variable canopy, cavity) and seven foraging guilds (aerial, bark, foliage, ground, nectar, raptor, tree driller). The Shannon-Weaver index was used as an indicator of species diversity (Shannon and Weaver 1949), where p_i is the relative density of each species. Species similarity (S_s) and population similarity (S_p) were calculated as indicators of the similarity of avian communities between sites (Legendre and Legendre 1983).

The following habitat variables were calculated as averages among the sampling quadrats and used in the analyses: tree density (TDE; stems/ha); tree basal area (TBA; m^2/ha); percent angiosperm tree basal area (THW; %); average tree diameter (TDI; cm); coefficient of variation of tree diameter (CVTDI; %); tree species richness (TSR); tree species diversity (TSD); shrub density (SDE; stems/ha); shrub basal area (SBA; m^2/ha); percent angiosperm shrub basal area (SHW; %); shrub species richness (SSR); shrub species diversity (SSD); total stem density (TST, as sum of TDE and SDE; stems/ha); total basal area (TOB, as TBA + SBA; m^2/ha); snag density (SND; stems/ha); snag basal area (SNB; m^2/ha); volume of coarse woody debris (CWD; m^3/ha); total vertical cover (VCV, as sum of cover in four 1-m intervals; %); percent shrub cover (SCV; average cover in three 1-m intervals above the ground; %); total ground cover (HCV; sum of all species of ground vegetation; %); canopy cover (CCV; %); coefficient of variation of vertical cover (CVVCV; %); canopy height (HGT, m). Note that some of these variables were used as indicators of the horizontal and vertical patchiness of selected habitat variables (Roth 1976). Coefficient of variation was calculated as the sample standard deviation divided by the mean (Zar 1984).

After viewing scatter plots of the densities of bird variables versus habitat variables, selected relationships were assessed using Pearson correlations. These correlations are intended for descriptive purposes, as rigorous use of this statistic is precluded by: the high within-stand variation of habitat variables, the high number of zero values for some habitat and avian variables, and the relatively small number of stands being compared.

Multivariate analyses were used to characterize avian "communities" (Gauch 1982). Hierarchical cluster analysis was used to group and classify the

sites by bird species densities (SYSTAT 1990). An average linkage cluster was used, using the unweighted pair-groups method, which calculates arithmetic averages (UPGMA; Sneath and Sokal 1973). The Pearson correlation was used for the similarity matrix in this cluster analysis (SYSTAT 1990). Two-way indicator species analysis (TWINSPAN; Hill 1979) was used to display the species in an ordered table, and facilitated classifying the bird species by habitat (Table 2).

Ordination techniques were used to explore the relationships among stands. Although we have a relatively low number of stands in comparison to the number of variables, ordination is nevertheless useful in showing trends, if they can be explained ecologically (Gauch 1982). We used two types of ordinations: one based on bird species data, and the other on habitat data. The ordinations of stands were compared to see if bird communities and habitat variables showed similar relationships among the stands. Detrended correspondence analysis (DCA) was used to analyze the bird species data, and allowed the plotting of bird species in relation to the study stands. Indirect gradient analysis was performed by correlating habitat variables to the DCA axes, using Pearson correlation coefficients.

Results and Discussion

Bird Density

A total of 72 bird species was recorded as breeding, foraging, or transient on at least one site (41 species had >1 territory/10 ha on at least one plot; Table 3). The total density of breeding birds ranged from 16.5 pairs/10 ha in the 3-yr-old plantation to 104.6 pairs/10 ha in the 15-yr-old plantation (Table 2). The reference, mixedwood stands ranged from 44.1 to 70.3 pairs/10 ha. Bird density reached pre-cutting (i.e., reference) levels within 5 years of plantation establishment, and peaked at 15 years.

TABLE 2. Summary of bird community variables. Species diversity is based on species breeding on the plot; richness includes species breeding and foraging.

Stand	Stand Age (yr)	Bird Density (pr/10 ha)	Species Diversity (H')	Species Richness
Plantation				
P3	3	16.5	1.71	17
P4	4	30.6	1.30	11
P5a	5	43.4	1.37	12
P5b	5	42.8	1.45	9
P6	6	54.3	1.88	18
P7a	7	48.3	1.77	20
P7b	7	56.2	1.41	12
P8	8	55.4	1.94	15
P13	13	84.6	2.13	27
P15	15	104.6	2.64	36
P21	21	86.0	2.59	24
Reference				
RM1	45	54.0	2.53	25
RA1	50	44.1	2.92	32
RC1	65	68.3	3.07	41
RC2	85	51.1	2.48	27
RM2	95	70.3	2.84	32

The densities of breeding birds are similar to those reported in other studies of conifer plantations and mixedwood and coniferous forest in northeastern North America. DesGranges (1980) found 66.7 pairs/10 ha in a mixedwood stand in La Mauricie National Park, Quebec. Welsh and Fillman (1980) reported 102–197 pairs/10 ha in clear-cuts of conifer forest aged 11–24 years in northwestern Ontario. Christie (1993) found 18.5–47.2 pairs/10 ha in forest plots in Fundy National Park. Parker et al. (1994) found 33.3–49.3 pairs/10 ha among stands of conifer forest and plantations up to 17-years old in southeastern New Brunswick. Additional relevant studies include Erskine (1977) and James and Peck (1995).

A peaking of avian density in mid-successional stands is a frequent observation in forest chronosequences (Probst 1979; Morgan and Freedman 1986). However, Parker et al. (1994) reported a more linear relationship of avian density and stand age in a chronosequence of plantations up to 17 years old.

Species Richness and Diversity

Species richness (including species using the site for nesting or foraging) ranged from 9 to 36 in the plantations, and from 25 to 41 among reference stands (Table 2). By 13 years, species richness in the plantations was similar to that in reference stands. However, the richness of breeding species (i.e., having a density of "+" or more) in plantations ranged from 7 to 22 (mean ± S.D., 11.8 + 4.9) compared with 18 to 31 in reference stands (24.2 + 5.1), a significant difference (ANOVA, $p < 0.001$).

Shannon-Weaver diversity (H') in reference stands ranged from 2.5 to 3.1. Plantations reached reference levels ($H' > 2.5$) after about 13 years (Table 2). The species diversity in younger plantations (3-8 years old) was 1.3 to 1.9, significant lower than in older plantations (2.1 to 2.6; $p < 0.001$; ANOVA). The older plantations provided habitat for species characteristic of both younger and older stages of succession, and this accounted for their relatively high diversity.

Similarity

Although the avian density, species richness, and species diversity reached levels similar to reference stands within 13 years, most of the bird species inhabiting the plantations were different from those in the natural forest. This observation is apparent in the matrices of species similarity (S_s) and population similarity (S_p) (Table 4). Despite differences in habitat among the reference stands, they were much more similar to each other than to the younger plan-

TABLE 3. Abundance of birds in the 16 study plots. Only species with at least 0.5 territory at one or more sites are listed here. "+" = <0.5 territory per plot; "V" = frequent visitor; "T" = transient occurrence. Nesting guilds: GN = ground nesting; SCN = shrub canopy; TD = tree canopy; VCN = variable canopy; H = cavity. Foraging guilds: aerial = A; bark = BG; foliage = F; ground = GS; nectar = N; raptor = P; tree driller = TD. Site codes are as in Table 1.

Species	Code	Guild Nest	Forage	P3	P4	P5a	P5b	P6	P7a	P7b	P8	P13	P15	P21	RM1	RA1	RC1	RC2	RM2
Ruffed Grouse	RUGR	GN	GS												V	1.5	1.7	0.5	1.0
Killdeer	KILL	GN	GS	0.4															
Common Snipe	COSN	GN	GS	1.3		1.0		1.0	V	1.0		1.0							
American Woodcock	AMWO	GN	GS					1.0	0.7								V		
Common Nighthawk	CONI	GN	A	0.4	1.0	V				T	1.0								
Ruby-throated Hummingbird	RTHU	TCN	N			V	V		V	V	V		V			O.7	+		V
Yellow-bellied Sapsucker	YBSA	H	TD												1.0	0.4	0.4		
Hairy Woodpecker	HAWO	H	TD												V	V	0.8	0.5	V
Eastern Wood-Pewee	EWPE	TCN	F											T	T	1.9			
Yellow-bellied Flycatcher	YBFL	GN	F									18.0	6.9	13.0		1.1	4.7	4.5	4.5
Alder Flycatcher	ALFL	SCN	F					5.3	4.3		6.0	T	13.4						
Blue-headed Vireo	SOVI	CN	FS										V	T	3.0	1.1	0.4	2.5	1.0
Red-eyed Vireo	REVI	CN	FS												2.0	4.5	T		
Tree Swallow	TRSW	H	A				1.0					V							
Black-capped Chickadee	BCCH	H	FS										+	1.0					1.0
Boreal Chickadee	BOCH	H	FS										+	+	3.0	v	+	V	2.0
Red-breasted Nuthatch	RBNU	H	BG						V			+	V	V	3.0	0.7	3.4	V	2.0
Brown Creeper	BRCR	TCN	BG														1.7	1.0	1.5
Winter Wren	WTWR	H	FS										+			T	2.1	1.0	0.5
Golden-crowned Kinglet	GCKI	CN	FS										2.0	8.0	2.0	1.1	4.2	6.0	6.0
Ruby-crowned Kinglet	RCKI	CN	FS					V				4.5	5.0	7.5			1.3	+	0.5
Eastern Bluebird	EABL	H	F			1.0													
Swainson's Thrush	SWTH	CN	GS										0.5	3.0	2.5	1.1	4.7	2.0	3.0
Hermit Thrush	HETH	GN	GS	V							0.5	0.5	2.0	2.0	2.0	2.2	2.5	T	
American Robin	AMRO	CN	GS	V	+	+	+	V	+	0.5		0.5	+	2.5		0.4	0.4		
Nashville Warbler	NAWA	CN	FS	V								V	3.5	3.0			0.8		
Northern Parula	NOPA	TCN	FS										V			2.6	1.3	1.0	0.5
Magnolia Warbler	MAWA	SCN	FS					1.9	V		0.5	9.0	13.4	8.5		2.2	10.6	2.0	7.0
Black-throated Blue Warbler	BTBW	SCN	FS												3.5	1.5	3.8	1.0	1.5
Yellow-rumped Warbler	TRWA	CN	FS									5.5	5.4	7.0	4.5	1.1	2.5	5.5	7.5
Black-throated Green Warbler	BTGW	TCN	FS									T	V	4.5	5.0	4.9	2.5	11.0	7.5
Blackburnian Warbler	BLWA	TCN	FS											6.5	9.5	4.5	5.1	4.0	5.0
Palm Warbler	PAWA	GN	FS					V	V	4.0	5.5	9.0	9.5	1.0					
Bay-breasted Warbler	BBWA	CN	FS											4.5	0.5	1.1	2.1	0.5	6.0
Blackpoll Warbler	BPWA	CN	FS										3.0						
Black-and-white Warbler	BWWA	GN	BG									T	V						1.0
American Redstart	AMRE	CN	F					V	V			T	1.5			3.7	V		1.0

(continued)

TABLE 3. *(continued)*

Species	Code	Guild Nest	Forage	P3	P4	P5a	P5b	P6	P7a	P7b	P8	P13	P15	P21	RM1	RA1	RC1	RC2	RM2
Ovenbird	OVEN	GN	GS												8.0	3.7	1.7	4.5	5.0
Mourning Warbler	MOWA	GN	FS	+				1.5	2.8								0.8		
Common Yellowthroat	COYE	GN	FS	0.9	2.0	3.0	8.0	15.0	9.2	4.0	11.0	10.0	15.3						
Wilson's Warbler	WIWA	GN	FS								+	T	3.5						
Canada Warbler	CAWA	GN	FS					V					V		T		2.1		
Song Sparrow	SOSP	GN	GS	4.8	8.0	18.5	11.0	4.4	7.1	21.0	9.5								
Lincoln's Sparrow	LISP	GN	GS	4.3	15.5	16.0	17.5	10.2	17.0	21.5	11.0	6.0	5.9						
Swamp Sparrow	SWSP	SCN	GS										1.5						
White-throated Sparrow	WTSP	GN	GS	+	3.5	3.0	4.0	12.6	5.3	4.0	9.5	18.0	8.4	9.5		0.4	1.7		+
Dark-eyed Junco	DEJU	GN	GS	3.5	+	+	1.0	1.0	1.1		0.5	2.0	2.5	4.0	2.0	0.4	2.5	2.0	4.0
Rose-breasted Grosbeak	RBGR	SCN	FS														0.4		
Pine Grosbeak	PIGR	SCN	FS															0.5	
Purple Finch	PRFI	TCN	FS									T	V		2.0	1.1	0.8	0.5	+

tations, and vice-versa. Because the middle-aged plantations (i.e., P13, P15, and P21) supported some species of younger habitats as well as some of mature forest, these stands tended to have relatively high values of S_s and S_p. The differences between reference forest and plantations were particularly great for S_p, because of the large differences in populations, even if there were some species in common. Overall, populations varied less between sites than did species composition.

Nesting and Foraging Guilds

The avian community of younger plantations was strongly dominated by ground-nesting species, particularly Common Yellowthroat (see Appendix 1 for binomials), Lincoln's Sparrow, Song Sparrow, and White-throated Sparrow. Ground-nesting birds accounted for 86–100% of the avian density in plantations aged 3 to 8 years, decreasing to 38–55% in the oldest plantations studied (15 and 21 years post-establishment) and 21–27% in the reference stands. In contrast, canopy-nesting species such as Magnolia Warbler, Ruby-crowned Kinglet, Yellow-bellied Flycatcher, and Yellow-rumped Warbler were most prominent in older stands. They accounted for 63–76% of the avian density in reference stands and 44–61% in the oldest plantations, compared with 0–12% in plantations aged three to eight years (Alder Flycatcher, which nests in shrubs, was the first species in this guild to invade the plantations, at six years post-establishment).

Cavity-nesting birds only occurred in significant numbers in reference forest, where the most prominent species were Black-capped Chickadee, Downy Woodpecker, Hairy Woodpecker, and Yellow-bellied Sapsucker. Although the plantations had few cavity-containing snags, any that did exist were used by such dependent species as Northern Flicker, Tree Swallow, American Kestrel, and Eastern Bluebird. The presence of natural cavities is well known as a limiting factor for these and other cavity-dependent species (Niemi and Hanowski 1984; Zarnowitz and Manuwal 1985; Adkisson 1988; Shreiber and Decalesta 1992; Freedman et al. 1996). In a separate study, artificially erected natural cedar cavities in plantations up to 17 years old were used by various species requiring this critical habitat element (including Boreal Chickadees, a forest species, in the 17-year-old stand; Freedman et al. 1996; Woodley et al., personal communication).

The most rapid shift in nesting guilds occurred in the 13–15 year-old plantations, which provided habitat suitable for similar numbers of species of ground- and canopy-nesters. This transition occurred much sooner after the clear-cutting of hardwood forest in Nova Scotia (Morgan and Freedman 1986), where vegetative regeneration (by stump-sprouting) of cut trees and angiosperm seedlings restored a shrub- and tree-level canopy much more quickly than in the

TABLE 4. Matrix of values of bird species similarity (S_s; left side of matrix) and population similarity (S_p; right side).

S_s/S_p	P3	P4	P5a	P5b	P6	P7a	P7b	P8	P13	P15	P21	RA1	RC1	RM1	RM2	RC2
P3	**1.00**	0.57	0.69	0.54	0.51	0.60	0.69	0.56	0.46	0.34	0.29	0.16	0.24	0.14	0.16	0.14
P4	0.47	**1.00**	0.70	0.70	0.41	0.45	0.61	0.62	0.37	0.21	0.23	0.19	0.15	0.17	0.14	0.11
P5a	0.40	0.80	**1.00**	0.76	0.47	0.63	0.83	0.59	0.41	0.29	0.22	0.18	0.19	0.11	0.18	0.10
P5b	0.39	0.82	0.80	**1.00**	0.44	0.55	0.67	0.58	0.39	0.27	0.18	0.20	0.16	0.06	0.15	0.06
P6	0.34	0.48	0.45	0.58	**1.00**	0.84	0.53	0.55	0.49	0.48	0.29	0.24	0.37	0.09	0.24	0.13
P7a	0.36	0.73	0.66	0.83	0.72	**1.00**	0.69	0.63	0.55	0.50	0.32	0.31	0.39	0.13	0.31	0.17
P7b	0.31	0.68	0.85	0.75	0.43	0.62	**1.00**	0.67	0.41	0.33	0.22	0.14	0.15	0.05	0.14	0.05
P8	0.31	0.60	0.55	0.68	0.76	0.73	0.58	**1.00**	0.52	0.43	0.26	0.21	0.18	0.15	0.21	0.14
P13	0.17	0.21	0.21	0.30	0.47	0.33	0.28	0.47	**1.00**	0.67	0.55	0.41	0.44	0.31	0.48	0.37
P15	0.14	0.18	0.17	0.27	0.49	0.36	0.23	0.50	0.68	**1.00**	0.63	0.59	0.62	0.39	0.59	0.54
P21	0.08	0.07	0.05	0.08	0.18	0.10	0.08	0.17	0.53	0.49	**1.00**	0.64	0.62	0.57	0.57	0.63
RA1	0.02	0.02	0.02	0.02	0.06	0.03	0.02	0.04	0.10	0.15	0.31	**1.00**	0.82	0.74	0.72	0.71
RC1	0.08	0.04	0.04	0.05	0.09	0.07	0.04	0.05	0.30	0.35	0.55	0.48	**1.00**	0.70	0.77	0.71
RM1	0.06	0.00	0.01	0.02	0.02	0.02	0.00	0.02	0.11	0.15	0.36	0.56	0.50	**1.00**	0.67	0.69
RM2	0.09	0.01	0.01	0.02	0.06	0.03	0.00	0.02	0.26	0.29	0.62	0.49	0.65	0.53	**1.00**	0.75
RC2	0.06	0.00	0.01	0.02	0.06	0.03	0.00	0.02	0.21	0.23	0.46	0.52	0.55	0.57	0.74	**1.00**

plantation chronosequence examined in the present study. Planted conifers have a relatively slow height growth compared with hardwood sprouts and seedlings, and plantation management includes the use of herbicide to release small conifers from the effects of competition.

Most species at all sites were ground searchers or foliage gleaners. Ground searchers varied little across the plantation chronosequence, accounting for 10–34% of the avian density in stands aged 3–8 years, and 14–26% in those aged 13–21 years, compared with 18–27% in reference forest. Prominent species in this guild included White-throated Sparrow and Ovenbird. Foliage searchers also varied little among these habitat types, accounting for 61–90% of the avian density in plantations aged 3–8 years, 52–64% in those aged 13–21 years, and 58–70% in reference forest. Prominent species in this guild included Common Yellowthroat and Yellow-rumped Warbler.

Other guilds were much less abundant. Species of the flycatcher guild were most abundant in plantations aged 6–21 years old, where their relative density ranged from 9 to 21%. Alder Flycatcher and Yellow-bellied Flycatcher were the most prominent species in this guild. Bark gleaners, such as Black-and-white Warbler, Red-breasted Nuthatch, and Brown Creeper, only occurred in reference forest, accounting for 2–7% of the avian density. Young plantations lack the foraging substrates for this guild (Franzreb and Ohmart 1978). Aerial foragers, such as Common Nighthawk and Tree Swallow, only occurred in plantations 8 years and younger, likely due to their preference for open nesting habitat (Ehrlich et al. 1988).

Prominent Bird Species

On average, six species accounted for 72% of the total avian density in plantations: Lincoln's Sparrow, 20.4%; Song Sparrow, 13.7%; Common Yellowthroat, 12.8%; White-throated Sparrow, 12.7%; Yellow-bellied Flycatcher, 6.2%; and Magnolia Warbler, 5.4%. Seven mostly different species accounted for 57% of the density in reference forest: Black-throated Green Warbler, 11.2%; Blackburnian Warbler, 10.1%; Ovenbird, 8.3%; Magnolia Warbler, 7.9%; Yellow-rumped Warbler, 7.6%; Golden-crowned Kinglet, 7.0%; and Yellow-bellied Flycatcher, 5.3%.

Habitat

A synopsis of selected habitat variables is presented in Table 5 (more detailed data are in Johnson (1997*), Fleming and Freedman (1998), and Veinotte et al. (2002*)). The plantation data illustrate the successional habitat changes occurring as the conifer forest develops. The average height of the canopy increased rapidly from about 1.1 m in a 3-year-old plantation to 6.9 m in the 21-year-old

TABLE 5. Summary of selected habitat variables (average data per stand).

Habitat variable	P3	P4	P5a	P5b	P6	P7a	P7b	P8	P13	P15	P21	RM1	RA1	RC1	RC2	RM2
Tree density (10^3/ha)	0	0	0	0	0.1	0	0.2	1.3	2.0	3.0	2.3	1.5	1.1	1.1	0.9	1.1
Tree basal area (m^2/ha)	0	0	0	0	0.2	0	0.4	3.6	9.4	10.8	17.4	29.8	29.3	25.4	28.1	28.1
Shrub density (10^3/ha)	19.1	5.6	5.2	6.1	26.4	16.1	6.4	14.7	10.9	21.3	9.7	13.8	17.8	12.0	11.9	12.3
Shrub area (m^2/ha)	0.85	0.95	0.93	1.51	4.65	4.73	1.76	3.67	0.84	6.19	1.02	1.77	1.86	2.41	2.75	2.29
Snag density (/ha)	0	0	25	0	0	0	0	50	0	0	13	185	138	708	485	200
Coarse woody debris (m^3/ha)	48.1	52.2	24.0	55.3	32.1	24.2	21.4	28.2	14.1	8.8	0.6	13.0	18.7	45.4	41.6	32.7
Tree canopy cover (%)	0	0	0	0	0	0	0	0	0	2	3	76	60	38	51	50
Shrub canopy cover (%)	1	1	1	2	38	19	9	30	71	81	93	51	46	58	64	74
Ground vegetation cover (%)	57	69	82	80	131	106	90	112	130	105	140	55	64	87	98	87
Canopy height (m)	1.1	1.9	1.8	2.1	4.0	3.0	2.7	3.8	5.9	5.3	6.9	15.9	10.6	13.7	16.6	13.4

plantation, compared with 10.6-16.6 m in reference stands (Table 5). Tree basal area increased steadily in plantations, achieving 17 m^2/ha in the 21-year-old stand, compared with 25–29 m^2/ha in reference stands. Trees in the plantations were predominantly the planted conifers, along with natural regeneration of balsam fir and a few hardwoods that survived the herbicide treatment. The reference stands, in contrast, are mixed-species communities of various coniferous and hardwood species (Table 1). Shrub density was variable among the plantations, largely depending on the relative abundance of certain angiosperm species, particularly *Sambucus racemosa* and *Spiraea latifolia.*

Snags were scarce in the plantations, having been depleted during the clear-cutting and subsequent site preparation. Snags were considerably more abundant in the reference forest (185–708/ha), partly because of mortality associated with past infestation with Spruce Budworm. Coarse woody debris was abundant in the younger plantations (48–52 m^3/ha in the 3- and 4-year-old stands), due to the recent deposition of logging slash. This deadwood component became progressively depleted as the plantations aged (to 0.6 m^3/ha in the 21-year-old stand). Coarse woody debris was relatively abundant in the reference stands (13–45 m^3/ha), due to the effects of tree mortality associated with Spruce Budworm. Further details on deadwood components in this chronosequence, including projections to plantation maturity and over several rotations, are in Fleming and Freedman (1998). Both snags and coarse woody debris are crucial elements of the habitat for a wide range of bird species and numerous other components of forest biodiversity (Newton 1994; Freedman et al. 1996).

The cover of ground vegetation increased rapidly during the first few years of plantation development, leveling off at about 100–140% in stands older than six years. The cover of ground vegetation was less in the reference stands, ranging from 55–98%, due to the relatively dense overhead canopy. Plant species of the youngest plantations were predominantly ruderal forbs (e.g., *Aster* spp., *Epilobium angustifolium*, and *Solidago* spp.) and graminoids (e.g., *Agrostis* spp. and *Scircus cyperinus*) that invaded the disturbed site, plus an *in-situ* regeneration of plants that survived the clear-cutting and site preparation (e.g., *Cornus canadensis, Dennstaedtia punctilobula*), and others that germinated from a persistent seedbank (e.g. *Rubus strigosus* and *Sambucus racemosa*). Details on species composition of the ground vegetation in this chronosequence are in Veinotte (1998*) and Veinotte et al. (2002*).

Multivariate Analyses

A cluster analysis was used to analyze the matrix of 41 bird species densities by 16 stands (Figure 1).

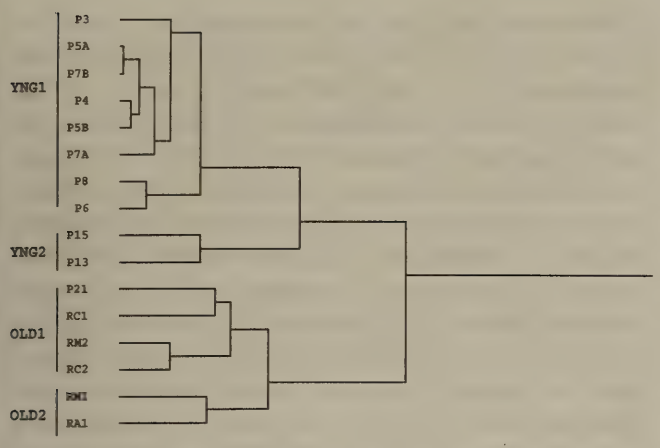

FIGURE 1. Dendrogram showing the results of the cluster analysis of 16 sites based on densities of 41 bird species.

The first division separated stands 15 years old and younger from older ones. A second division resulted in a total of four distinct clusters:

- YNG1 consists of the youngest plantations, aged 3 to 8 years. Breeding birds common to all stands in YNG1 include Common Yellowthroat, Song Sparrow, Lincoln's Sparrow, and White-throated Sparrow. Dark-eyed Junco was present at all but one site. This group is comprised of ground-nesting, open-canopy species.
- YNG2 includes intermediate-aged plantations aged 13 and 15 years. Birds occurring in both sites include Yellow-bellied Flycatcher, Ruby-crowned Kinglet, Hermit Thrush, Magnolia Warbler, Yellow-rumped Warbler, Palm Warbler, Common Yellowthroat, Lincoln's Sparrow, White-throated Sparrow, and Dark-eyed Junco. These species are a mixture of ground-nesting and forest-nesting species capable of inhabiting young, second-growth coniferous forest.
- OLD1 consists of the most conifer-dominated reference stands (RM2, RC1, and RC2) plus the oldest plantation (P21). Birds occurring in all stands of this group include Yellow-bellied Flycatcher, Golden-crowned Kinglet, Ruby-crowned Kinglet, Swainson's Thrush, Magnolia Warbler, Yellow-rumped Warbler, Black-throated Green Warbler, Blackburnian Warbler, Bay-breasted Warbler, and Dark-eyed Junco. These are mostly canopy-nesting species of coniferous or conifer-dominated mixedwood forest.
- OLD2 consists of the most angiosperm-rich reference stands (RA1 and RM1). Birds common to this cluster include Yellow-bellied Sapsucker, Golden-crowned Kinglet, Swainson's Thrush, Hermit Thrush, Blue-headed Vireo, Red-eyed Vireo, Black-throated Blue Warbler, Yellow-rumped Warbler, Black-throated Green Warbler, Blackburnian Warbler, Bay-breasted Warbler, Ovenbird, Dark-eyed Junco, and Purple Finch. These species are either typical of mature hardwood forest, or of hardwood-dominated mixedwood. Most are canopy-nesting species, except for three ground nesters (Hermit Thrush, Ovenbird, and Dark-eyed Junco).

The data matrix of bird density for 16 stands was also analyzed by detrended correspondence analysis (DCA). A subset of the 41 most abundant species was used, excluding rare species that could have a disproportionate effect on the results of the DCA. Indirect gradient analysis was then performed by correlating habitat variables with the DCA axes. The first axis of the DCA explained 43% of the variance, and was negatively correlated to habitat variables that had their highest values in reference stands (Table 6). This axis separates the reference stands from the young plantations, with older plantations in between (Figure 2). Although the data are not presented here, the ordination of bird species on Axis 1 clearly separates species of mature reference forest from those of younger plantations. The second DCA axis explains much less of the variation (5.2%) and has relatively weak associations with habitat variables. It is most strongly related to high shrub basal area and stem density, as well as high total cover of ground vegetation.

Both the cluster analysis and the ordination support the following observations: (a) the avian "communities" of younger plantations are dissimilar to those of both reference forest and older plantations, (b) as plantations age they become somewhat similar to reference forest in their avian community, and (c) like-aged stands support similar avian communities. However, the oldest plantations that we studied (15 and 21 years post-establishment), which are about 1/3 to 1/2 of their harvest rotation, are quite different from the natural, reference forest in terms of the structure and complexity of their habitat and vegetation, and to a lesser degree in their avian community.

General Discussion

Clear-cutting and the subsequent establishment of conifer plantations result in temporary habitat opportunities for open-canopy species of birds, such as Alder Flycatcher, Common Yellowthroat, Song Sparrow, and Lincoln's Sparrow. Interestingly, some of these species are relatively uncommon in Fundy National Park. The total populations of Song Sparrow and Lincoln's Sparrow in 1992 were estimated as fewer than 100 pairs each, and that of Alder Flycatcher about 130 pairs (Christie 1993*).

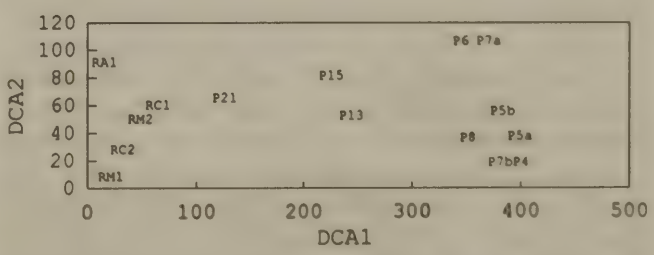

FIGURE 2. Study sites displayed on the first two axes of a Detrended Correspondence Analysis performed using densities of 41 bird species in 16 study sites.

TABLE 6. Correlations between habitat variables and the first two axes of a detrended correspondence analysis performed using the densities of the 41 most abundant bird species in 16 study stands. Axis 1 accounted for 43.4% of the variance, and axis 2 5.2%. See Methods section for explanation of habitat acronyms.

Habitat Variables	DCA Axis 1	DCA Axis 2
TBA	-0.993	-0.036
TOB	-0.990	0.037
CVTDI	-0.968	-0.067
TDI	-0.945	0.024
HGT	-0.938	-0.087
TSR	-0.903	0.160
CCV	-0.870	-0.160
AGE	-0.862	-0.050
THW	-0.818	-0.026
TSD	-0.807	0.205
SCV	-0.739	0.300
SNB	-0.692	-0.118
VCV	-0.688	0.333
SND	-0.653	-0.091
SHW	-0.571	-0.021
TDE	-0.549	0.146
SBA	0.070	0.553
HCV	0.105	0.521
TST	-0.241	0.501
SDE	-0.163	0.499
SSR	-0.082	0.457

r = 0.742; p = 0.001
r = 0.623; p = 0.01
N = 16, df = 14

In addition, Common Nighthawk may not be breeding in the national park (Christie 1993*), but it utilizes habitat in nearby clear-cuts and young plantations. Silvicultural practices such as thinning and herbicide use help to maintain plantations in a relatively open condition for an extended period of early-successional time, perhaps prolonging their suitability for some of these species (MacKinnon and Freedman 1993).

As the plantations mature they provide habitat for some species that inhabit conifer-dominated forest, such as Yellow-bellied Flycatcher, Ruby-crowned Kinglet, Nashville Warbler, Magnolia Warbler, and Yellow-rumped Warbler. We did not have the opportunity to examine plantations older than 21 years (because none existed in our study area). However, based on observations of natural conifer-dominated forest and our oldest plantation, we predict that plantations older than about 25 years would also provide habitat suitable for Golden-crowned Kinglet, Blackburnian Warbler, Bay-breasted Warbler, Black-throated Green Warbler, and Cape May Warbler, as well as some other species. In addition, if older plantations are adjacent to natural forest, they are utilized as foraging habitat by some forest species, such as Black-capped Chickadee, Boreal Chickadee, and Red-breasted Nuthatch.

However, a total of 16 species that bred in natural reference forest were not observed in plantations, including species that prefer or require mature habitat with a significant component of angiosperm trees, and those that require cavities. In our study area, species that will probably become at risk from the extensive conversion of hardwood-dominated or mixedwood stands into coniferous plantations include Ovenbird, Red-eyed Vireo, and Black-throated Blue Warbler (see also Finch 1991; Baguette et al. 1994; Donald et al. 1998; Easton and Martin 1998). As noted previously, all cavity nesters are at risk from plantation management of the type we studied, which results in the destruction of all or most snags during clear-cutting and site preparation. Moreover, there are poor prospects for the development of new cavity trees during subsequent plantation rotations (Fleming and Freedman 1998).

Proposed Mitigations

Although our research was not specifically designed to test hypotheses directly related to habitat mitigations, we believe that we can make several useful recommendations based on the results of this study. We stress, however, that these recommendations should be subjected to field tests to ensure that they are efficacious.

In any forest-management area, reasonably sized patches of all naturally occurring forest types should be protected from conversion into plantations or other kinds of anthropogenic ecosystems. We cannot make specific suggestions about the sizes of the protected areas, but they should be large enough to be self-maintaining over the longer term. If this is done, then most indigenous species of birds, and other elements of native biodiversity, should be able to maintain viable populations in the management area. In our study area (the Greater Fundy Ecosystem), we recommend that forest managers should ensure that adequate areas of closed-canopy, mixedwood, and angiosperm-dominated forest remain available to provide habitat for species for which plantations appear to be unacceptable. In part, this objective could be achieved by allowing some clear-cuts and other harvested areas to regenerate naturally after logging.

Areas converted to plantations should be allowed to retain or regenerate a substantial component of deciduous trees. In part, this could be achieved by deliberately leaving some areas untreated during herbicide sprays. In fact, about 10% of treated areas are "missed" during typical silvicultural herbicide applications (Santillo et al. 1989; MacKinnon and Freedman 1993). We recommend that the non-sprayed area should be at least twice as large as this, to ensure that the overall habitat retains sufficient islands of hardwood shrubs and trees for dependent species.

Ensuring the persistence of snags, cavity trees, and coarse woody debris is also necessary to

maintain populations of species dependent on these critical habitat elements. Woodley and Forbes (1997*) have recommended that 10–12 snags (>20 cm DBH) plus 12–15 live mature aspen (*Populus* spp.) or beech (*Fagus grandifolia*) be retained per hectare, preferable in clumps of at least 25 m^2, to provide these habitat elements in clear-cuts and plantations in the Greater Fundy Ecosystem. It is also necessary to ensure that new cavity trees develop during subsequent plantation rotations. We believe that this could result if "islands" of uncut, mature, hardwood-dominated forest are retained within clear-cuts and plantations. We recommend that these tree-islands should be at least 1 hectare in area, and should be present in at least a 1:10 ratio to area of clear-cut or plantation. Although the ecological integrity of these tree-islands will be challenged by their small area, high edge ratio, and silvicultural practices occurring around them, they should prove capable of maintaining a sufficient number of cavity trees, snags, and coarse-woody debris to maintain populations of at least some dependent species within the management block (Jansen et al. 1995). To some degree, riparian buffer strips adjacent to clear-cuts and plantations may provide these habitat elements, although this service would be degraded if these linear features are selectively harvested of their larger trees. More detailed recommendations about deadwood elements of habitat in the GFE are in Woodley and Forbes (1997).

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Appendix 1.

Scientific names of bird species.

Ruffed Grouse, *Bonasa umbellus*
Killdeer, *Charadrius vociferus*
Common Snipe, *Gallinago gallinago*
American Woodcock, *Scolopax minor*
American Kestrel, *Falco sparverius*
Common Nighthawk, *Chordeiles minor*
Ruby-Throated Hummingbird, *Archilochus colubris*
Yellow-Bellied Sapsucker, *Sphyrapicus varius*
Hairy Woodpecker, *Picoides villosus*
Downy Woodpecker, *Picoides pubescens*
Northern Flicker, *Colaptes auratus*
Eastern Wood-Pewee, *Contopus virens*
Yellow-Bellied Flycatcher, *Empidonax flaviventris*
Alder Flycatcher, *Empidonax alnorum*
American Robin, *Turdus migratorius*
Blue-headed Vireo, *Vireo solitarius*
Tree Swallow, *Tachycineta bicolor*
Black-Capped Chickadee, *Parus atricapillus*
Boreal Chickadee, *Parus hudsonicus*
Red-Breasted Nuthatch, *Sitta canadensis*
Brown Creeper, *Certhia americana*
Winter Wren, *Troglodytes troglodytes*
Golden-Crowned Kinglet, *Regulus satrapa*
Ruby-Crowned Kinglet, *Regulus calendula*
Eastern Bluebird, *Sialia sialis*
Swainson's Thrush, *Catharus ustulatus*
Hermit Thrush, *Catharus guttatus*
Red-Eyed Vireo, *Vireo olivaceus*
Nashville Warbler, *Vermivora ruficapilla*
Northern Parula, *Parula americana*
Magnolia Warbler, *Dendroica magnolia*
Cape May Warbler, *Dendroica tigrina*
Black-Throated Blue Warbler, *Dendroica caerulescens*
Yellow-Rumped Warbler, *Dendroica coronata*
Black-Throated Green Warbler, *Dendroica virens*
Blackburnian Warbler, *Dendroica fusca*
Palm Warbler, *Dendroica palmarum*
Bay-Breasted Warbler, *Dendroica castanea*
Blackpoll Warbler, *Dendroica striata*
Black-and-White Warbler, *Mniotilta varia*
American Redstart, *Setophaga ruticilla*
Ovenbird, *Seiurus aurocapillus*
Mourning Warbler, *Oporornis philadelphia*
Common Yellowthroat, *Geothlypis trichas*
Wilson's Warbler, *Wilsonia pusilla*
Canada Warbler, *Wilsonia canadensis*
Song Sparrow, *Melospiza melodia*
Lincoln's Sparrow, *Melospiza lincolnii*
Swamp Sparrow, *Melospiza georgiana*
White-Throated Sparrow, *Zonotrichia albicollis*
Dark-Eyed Junco, *Junco hyemalis*
Rose-breasted Grosbeak, *Pheucticus ludovicianus*
Pine Grosbeak, *Pinicola enucleator*
Purple Finch, *Carpodacus purpureus*

Testing a Double-Count Aerial Survey Technique for White-Tailed Deer, *Odocoileus virginianus*, in Québec

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In a double-count aerial survey, two independent observers, located on the same side of an aircraft, simultaneously count animals in sample plots. To evaluate if this technique could be implemented as part of our White-Tailed Deer (*Odocoileus virginianus*) management program, we assessed its precision to estimate densities over large wintering areas (≥ 25 km^2, 10 surveys) and whole hunting zones (1600-26 000 km^2, 14 surveys). We also tested its repeatability by replicating eight surveys two to five times. We finally compared double-count aerial surveys with pellet-group counts, which were previously used to estimate deer numbers. Surveys of large wintering areas indicated that a 90% confidence interval (CI) of ± 20% could be obtained with a sample size of 50–100 plots (5 km × 60 m strip plots). In hunting zones, 100–200 plots would have been needed to reach the same precision. Densities from replicated surveys were not considered biologically different (difference > 30% between two replicates within each survey) for 21 of 24 replicates overall. When both techniques were applied to the same wintering areas, the 90% confidence limits of the aerial estimate encompassed the pellet-group estimate in five of nine surveys, and was lower in one survey and was higher in three surveys. Although the costs of the aerial survey and the pellet-group count techniques are rather similar, we suggest that aerial surveys provide better estimates. We conclude that the double-count technique is reliable to survey White-Tailed Deer at a reasonable cost. In our context, a typical zone (200 plots) requires 30–40 helicopter hours and 10 days of work by a three-person crew.

Key Words: White-Tailed Deer, *Odocoileus virginianus,* aerial survey, double count, Petersen estimate.

Aerial surveys are commonly used to estimate the size of large mammal populations, notably Caribou (*Rangifer tarandus*), Elk (*Cervus elaphus*), and Moose (*Alces alces*) (Courtois et al. 1994; Couturier et al. 1996; Gasaway and Dubois 1987; Eberhardt et al. 1998). Such surveys are less common for White-Tailed Deer (*Odocoileus virginianus*) and Mule Deer (*O. hemionus*), as most jurisdictions rely on harvest statistics to manage populations. Pellet-group counts (Neff 1968) have historically been used to estimate deer numbers. Aerial surveys for deer have been conducted in several vegetation types: brush-dominated habitats in Texas (Beasom 1979; Beasom et al. 1981), Pinion Pine (*Pinus edulis*) – Juniper (*Juniperus osteosperma*) in Colorado (Kufeld et al. 1980; Bartmann et al. 1986, 1987; White et al. 1989), and deciduous forest in Connecticut (Kilpatrick and Ellingwood 1993), Missouri (Beringer et al. 1998) and Ohio (Stoll et al. 1991). This technique is difficult to apply in coniferous or mixed conifer-deciduous forests because of the closed tree canopy. Thermal imagery appears as a promising technique, particularly in deciduous forest, but is not yet feasible under coniferous cover (Gill et al. 1997; Havens and Sharp 1998).

Using correction factors in aerial surveys might be an alternative in coniferous forest landscapes. Correction factors should be specific to each survey, as many authors (Pollock and Kendall 1987; Graham and Bell 1989; Marsh and Sinclair 1989; Seber 1992) pointed out that it might be biased to use a correction factor obtained in one area under one set of conditions for another area or under different conditions. To evaluate and correct the sighting probability, Floyd et al. (1979) and Beringer et al. (1998) have used radio-collared deer, a costly approach. Hence, a technique incorporating survey-specific correction factors in its application at a low cost is needed. The double-count technique provides such a survey-specific estimate of the sighting probability. This method relies on two observers searching independently all the parcels sampled and reporting their findings to a third party so that animals seen in common or detected only by one observer can be tallied. Correction factors can be estimated with the Petersen model (Seber 1982; Pollock and Kendall 1987).

We tested the double-count technique for White-Tailed Deer on Anticosti Island (Potvin et al. 1992; Rivest et al 1995) and in different areas on the Québec mainland. Our objective was to evaluate if this technique could be implemented as part of our provincial deer management program, based on (1) precision and repeatability of the density estimates under different conditions and (2) comparison of deer number estimates and costs with the pellet-group count, the technique that was previously used.

Study areas

The double-count aerial survey technique was tested in Québec in eight large deer wintering areas (25–213 km^2), two forest blocks (160 and 475 km^2) on Anticosti Island (zone 20), and 11 hunting zones (1 600–26 000 km^2) on the mainland (Figure 1). Deer continuous distribution in the province is limited to those zones. Southern zones (4, 5, 6, 7, 8) have a mixed agriculture-forested landscape while northern zones (1, 2, 3, 9, 10, 11, 20) are largely forested. Vegetation types are mostly deciduous or mixed, except on Anticosti Island which is dominated by boreal forest. During the snow season, deer congregate in wintering areas with a dense mixed and coniferous canopy. Winters are milder in the south, with three to four months of snow cover, but severe in the northern and eastern parts of the deer range, with almost six months of snow. Snow depth rarely exceeds 50 cm in the southern zones but can do so for 30 to 70 days on average in northern ones.

Methods

Aerial survey technique

A detailed description of our double-count aerial survey technique can be found in Breton and Potvin (1997). Deer were counted by two observers sitting on the left side of a Bell 206-B (Anticosti) or Bell 206-L (other zones) helicopter. A bubble window installed in the back door enabled the rear observer to see under and beside the aircraft. The front observer used the front upper, side and floor windows. The width of the narrow strip plot extended on the left side only from 0° (below the helicopter) to a 45° angle from the vertical. For each observer, the outer boundary was delimited by two reference marks denoted by plastic tape, on the side window and on the bottom of a rod extending outside and perpendicular to the aircraft. Before each survey, the helicopter followed a straight line (road, air strip) so that both observers verified that their viewing angles were identical.

The navigator sat in the back seat behind the pilot and used a bubble window to provide front and lateral vision. He was responsible for discriminating and recording the deer groups seen. To ensure independence between the observers, the front observer, navigator, and pilot were connected to the communication system of the aircraft and the rear observer was in contact with the navigator through a portable system. The earphones of the navigator were modified in such a way that one ear was connected to the helicopter system and the other to the portable one. A switch enabled the navigator to speak separately to either observer.

Surveys were conducted in winter. The survey area was delineated on 1:50 000 topographical maps. Large wintering areas were covered by systematic sampling and a 1–km buffer was usually added to

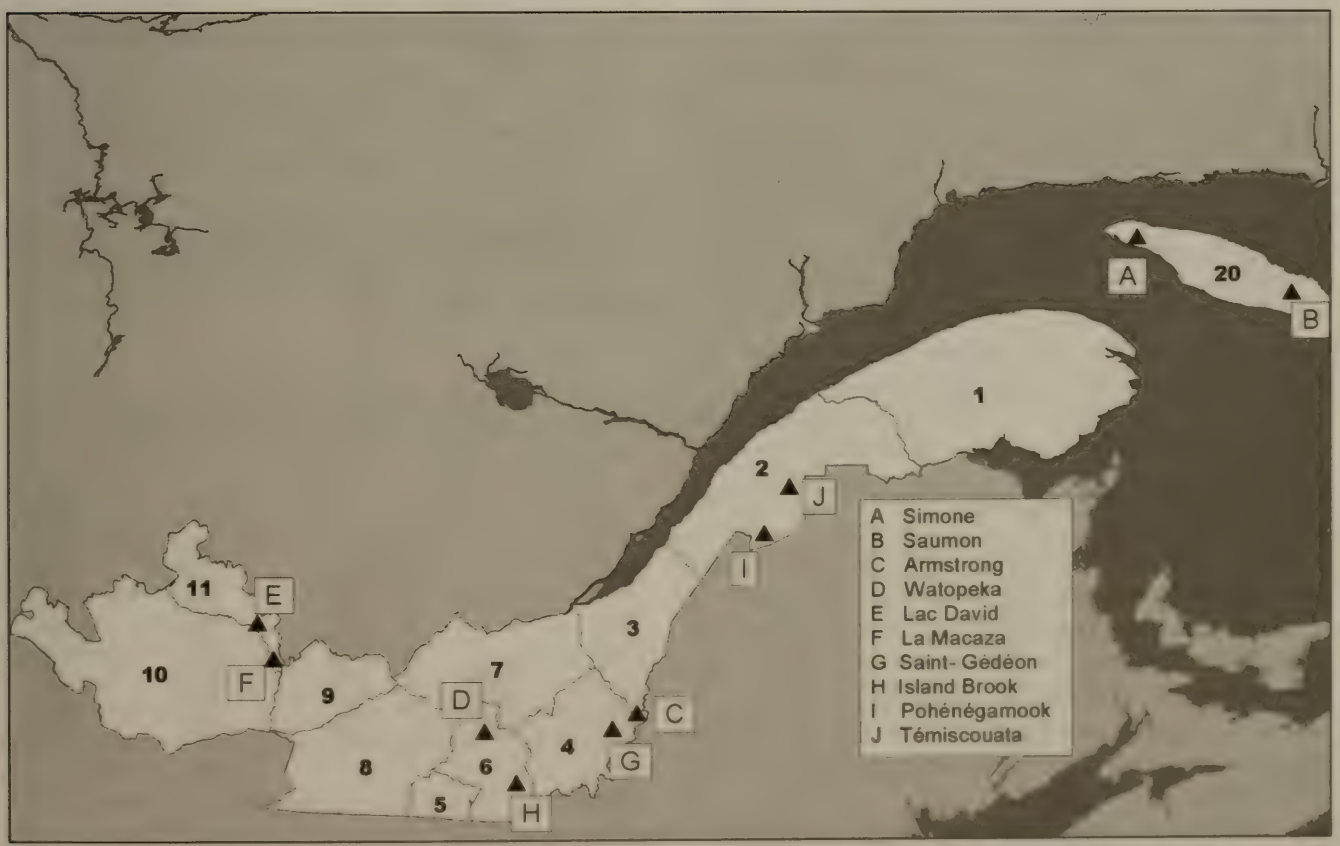

FIGURE 1. Location of hunting zones (1-20), forest blocks (A, B) and deer wintering areas (C-J) where the double-count aerial survey technique was applied in Québec.

their periphery to include deer that might be outside of the traditionnal boundary of the yard. For hunting zones, three different sampling strategies were used depending on deer distribution: (1) systematic sampling of all forested areas in zones where deer were uniformly distributed and at high density (zone strategy), (2) systematic sampling with survey limited to wintering areas > 2.5 km^2 in zones with sparse distribution (yards strategy), and (3) stratified sampling with survey of both forested and wintering areas, for zones in between (mixed strategy). Strip plots 5–km long (6 km in earlier tests on Anticosti Island) were systematically distributed on the survey area along parallel lines oriented along a north-south azimuth. The same distance usually separated plots and lines to provide a complete systematic survey plan. Non-forested areas (lakes, agricultural and suburban areas) occupying > 300 m along the line were excluded as they are not deer habitat. Therefore, survey plots were often discontinuous and made up of segments, especially in agro-forested landscapes. At the periphery of the survey blocks, incomplete plots on a line extended to the next line to cumulate 5 km.

Loran-C (earlier surveys) or GPS navigation systems of the aircraft were used to keep the bearing (Boer et al. 1989; Leptich et al. 1994). The pilot used the longitude reading to stay on line or to change lines (Beringer et al. 1998). The navigator determined the beginning and the end of plots along lines using visual features or latitude readings. The pilot kept an altitude of 60 m, verified by a radar altimeter, and a speed of 70 to 100 km/hr.

Observers counted deer groups and classified them according to size (1, 2, 3, etc.) and activity (moving or inactive [bedded or standing immobile]). The navigator recorded deer sightings directly on the map and separately for each observer. Observers reported groups at the moment they were perpendicular to the helicopter, even if they had been detected in advance. Deer that had moved outside the strip before the passage of the helicopter were recorded if they were inside when initially seen. Groups located outside the strip were not tallied. When observers counted a different number of deer in a group, the higher value was used as group size in the computations.

Computation of sighting probabilities and deer densities

Because of the 45° viewing angle, the width of the strip is equal to the altitude (60 m), giving an area of 0.3 km^2 per plot (5 km × 60 m). A study area contains M plots where m of these are surveyed so that $f = m/M$ is the sampling fraction. Let $h = 1, ..., H$, and $i = 1, ..., m$ denote the subscripts representing the group size and the parcel sampled, respectively. The following notation is used:

n_{ihk} = number of groups of h animals in parcel i seen by front observer only ($k = 1$), rear observer only ($k = 2$) or both observers ($k = 3$),

$n_{.hk}$ = sum of the n_{ihk}'s for m parcels sampled,

$n_{ih.}$ = total number of groups of h animals seen in parcel i ($n_{ih.} = n_{ih1} + n_{ih2} + n_{ih3}$),

$n_{.h.}$ = total number of groups of h animals seen in m parcels surveyed.

For sighting probabilities, we consider four group sizes: single deer, groups of two, groups of three, and groups of four or more. Sighting probabilities by observer (p_{hk}) are computed according to the Petersen estimate (Magnuson et al. 1978) for each group size:

$$p_{h1} = \frac{n_{.h3}}{(n_{.h2} + n_{.h3})}, \text{ and } p_{h2} = \frac{n_{.h3}}{(n_{.h1} + n_{.h3})}.$$

The total population of deer and its variance are estimated using equations proposed by Rivest et al. (1995). These estimates use three correction factors (c_h), one for single deer, one for groups of two deer, and one for groups of three deer:

$$c_h = 1 + \frac{n_{.h2} n_{.h1}}{n_{.h.}(n_{.h3} + 1)}.$$

For groups of four deer or more, we assume a correction factor of 1 (no correction). Based on 25 surveys, the sighting probability for such groups was on average 0.92 and 0.90 for the front and rear observer, respectively (Figure 2). Since at least one observer had a sighting probability of 1.00 in 17 of these surveys, the correction factor $c_4 = 1$ most of the time. The variance estimator for c_h is computed as follows:

$$\text{var}(c_h) = \frac{(c_h - 1)[c_h(n_{.h.} - n_{.h3} - 2) + 1]}{(n_{.h.} - 1)(n_{.h3} + 2)}.$$

An estimate of the total number of deer in each parcel (N_i), its variance and deer population in the survey area (T) is given by:

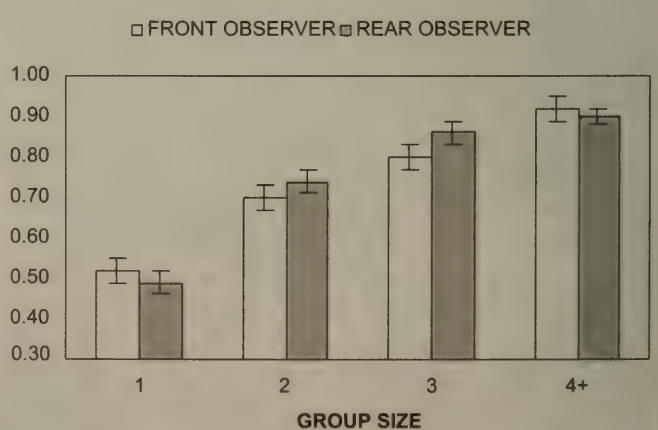

FIGURE 2 Sighting probability (± 1 SE) of the front and rear observers according to group size obtained in 25 double-count aerial surveys in Québec.

$$N_i = c_1 n_{i1.} + 2c_2 n_{i2.} + 3c_3 n_{i3.} + \sum_{h=4}^{H} h n_{ih.} ,$$

$$\text{var}(N_i) = [1/(m\text{-}1)] \left[\sum_{i=1}^{m} N_i^2 - \left(\sum_{i=1}^{m} N_i\right)^2 / m\right] ,$$

$$T = (1/f) \sum_{i=1}^{m} N_i .$$

The variance of T has three components due to the variability of the selection of m parcels (σ_s^2), the estimation of the correction factors (σ_e^2), and the prediction of the number of deer (σ_p^2):

$$\sigma_s^2 = [1/f(1\text{-}f)\, M\ \text{var}N_i] - (1\text{-}f)\, \sigma_p^2 ,$$

$$\sigma_e^2 = (1/f^2)\, [n_{1.}^2 \text{var}(c_1) + 4n_{2.}^2 \text{var}(c_2) + 9n_{3.}^2 \text{var}(c_3)] ,$$

$$\sigma_p^2 = (1/f^2)\, \{n_{1.}[c_1^2 - c_1 - v(c_1)] + 4\, n_{2.}[c_2^2 - c_2 - v(c_2)] + 9\, n_{3.}[c_3^2 - c_3 - v(c_3)]\} ,$$

$$\text{var}\, T = \sigma_s^2 + \sigma_e^2 + \sigma_p^2 .$$

This variance is slightly larger than that presented by Rivest et al. (1995: Table 1) because some correction terms have been omitted to simplify formula expression. To allow comparison among study areas, results are generally presented in terms of density ($\bar{x}$) and its standard error (SE), based on the extent of the study area (AREA):

$$\bar{x} = T / \text{AREA}, \text{ and SE} = (\sqrt{\text{var}T}) / \text{AREA} .$$

Assessing precision and repeatability

Statistical precision depends on deer distribution "variability" and sample size. We used an α level = 0.10, as suggested by Tzilkowski and Storm (1993) for White-Tailed Deer management decisions. For Moose aerial surveys, a 90% CI of ± 20–25% is the target precision (Crête et al. 1986; Gasaway et al. 1986). For large-scale field studies, population densities within ± 20% of the true mean at α = 0.10 are considered reasonable precision and accuracy goals (Lancia et al. 1994). Our objective was set at a 90% CI of ± 20%. We computed the 90% CI of the deer density estimate in 10 surveys of wintering areas and 14 surveys of hunting zones, using the simple random sampling formula and assuming that f was negligible (Cochran 1977):

$$90\%\ \text{CI}\ (\%) = \pm (t_{0.10}\ \text{SE}\ / \bar{x}) \times 100 .$$

We also evaluated sample size needed to reach a CI of ± 20%, assuming f was negligible:

$$\text{Sample size} = m\ (90\%\ \text{CI} / 20)^2 .$$

To test repeatability (temporal sampling error) of the double-count technique, we replicated eight surveys two to five times each to verify if results were consistent within each survey. On Anticosti Island, three surveys were repeated on different days. On the mainland, five large deer wintering areas were surveyed two or more times over the same winter. The observers and navigator were the same within each survey except for one survey on Anticosti Island. We compared deer densities among replicates within each survey by examining if the 90% CI overlapped. We also verified if the results from two replicates differed by more than 30%, a difference we assume to be biologically significant (Steidl et al. 1997) considering the rapid population dynamics of deer at our latitude (Lamontagne and Potvin 1994).

Comparison with the pellet-group count technique

The pellet-group count technique has historically been used to estimate deer numbers in large wintering areas in Québec and elsewhere (Neff 1968; Potvin 1995). We compared aerial survey and pellet count techniques for nine deer yards where both techniques were applied. Pellet groups were counted in 1/125 ha plots in early spring prior to green up. The deer density estimate was based on the mean number of pellet-groups per plot ($\bar{y}$), defecation rate (26 pellet groups per day), duration of the period

TABLE 1. Precision obtained and sample size required for a 90% CI of ± 20% in 10 aerial surveys of deer wintering areas using the double-count technique to estimate deer density in Québec.

Survey (area – year)	m plots	Deer/km²			Number of plots required
		($\bar{x}$[a])	SE	90% CI[b]	
Armstrong 1989	25	13.7	2.3	29	50
Armstrong 1991	35	11.6	1.7	25	55
Watopeka 1990	89	4.4	0.7	27	150
Lac David 1990	60	8.8	1.3	25	95
La Macaza 1990	62	11.9	1.8	25	100
St. Gédéon 1991	26	8.6	1.2	24	40
Island Brook 1991	32	12.4	1.5	20	35
Pohénégamook 1994	61	19.2	1.1	10	15
Pohénégamook 1996	39	20.0	1.9	15	25
Témiscouata 1995	34	9.6	1.6	29	70

[a]Most surveys included a 1-km buffer. Densities are for the whole area surveyed, including the buffer.
[b]Expressed as % of mean estimate.

when deer were in the wintering area in days (PERIOD), and size of the wintering area in ha (SIZE):

$$\text{Deer number} = (125 \times \bar{y} \times \text{SIZE}) / (26 \times \text{PERIOD})$$

A defecation rate of 13 pellet groups per day is often used, following Eberhardt and van Etten (1956). However, more recent studies indicated that the actual rate in winter is 26 pellet groups per day (Rogers 1987; Sawyer et al. 1990). Statistical precision of $\bar{y}$ is usually between ± 10 and ± 20% because of large sample size (> 250 plots). Nonetheless, it was not possible to evaluate the global precision of the deer population estimate because the variability of the other variables (defecation rate, SIZE, and PERIOD) is unknown. This precluded the use of a statistical test between the aerial survey and pellet-group count deer estimates. Therefore, we considered that both estimates were similar if the 90% confidence limits of the aerial estimate encompassed the estimate of the pellet-group count. We also compared the cost of both techniques using figures obtained from our surveys.

Results

Precision and repeatability

In wintering areas, the 90% CI in 10 surveys varied from ± 10 to ± 29% (Table 1). To reach a ± 20% precision, sample sizes of 50 to 100 plots would suffice. Precision was more variable in hunting zones, ranging from ± 13 to ± 49% (Table 2). In general, zones where sampling was limited to wintering areas provided narrower CI than those where all forested areas were surveyed. In most hunting zones, 100 to 200 plots would be necessary to achieve a 90% CI of ± 20%.

Assessment of repeatability was based on eight surveys that were replicated two to five times, totalling 24 replicates (Table 3). The time delay between replicates of a specific survey ranged between 2 and 86 days. Deer densities 90% CI overlapped among replicates within any survey. Three surveys each had a single replicate that had a difference > 30% in density with other replicates of the same survey.

Comparison with the pellet-group count technique

Confidence limits for aerial survey deer estimates encompassed pellet-group count estimates in five of nine surveys of wintering areas (Table 4). Estimates from aerial survey were lower in one survey and higher in three surveys.

Pellet-group counts take approximately 40 man-days to survey a single large wintering area (≥ 25 km^2). Based on $200 CDN / person-day for salaries and $125 / day for travel expenses, this amounts to $13 000. A similar survey for a whole hunting zone costs about $32 500. The aerial survey of a large wintering area necessitates about 60 plots, which amounts to $8 600 for the helicopter ($1000/hr × 60 plots/7 plots per hr) and six person-days, for a total of $10 500. Surveying a hunting zone amounts to $33 300 for the helicopter ($1000/hr × 200 plots/6 plots per hr) and 30 person-days, for a total of $43 000.

Discussion

The double-count technique provided precise and repeatable estimates of White-Tailed Deer density at a reasonable cost. Sample size needed to achieve a 90% CI of ± 20% for either wintering areas (50 to 100 plots) or hunting zones (100 to 200 plots) was relatively small. Much smaller plots (5 km × 60 m)

TABLE 2. Precision obtained and sample size required for a 90% CI of ± 20% in 14 aerial surveys of hunting zones using the double-count technique to estimate deer density in Québec.

Sampling strategy[a]	Survey (zone - year)	*m* plots	Deer/km^2			Number of plots required
			($\bar{x}$[b])	SE	90% CI[b]	
A	5 - 1990	61	9.9	1.9	32	160
	5 - 1992	170	12.5	1.1	14	85
	6 - 1990	82	3.1	0.6	31	190
	8 - 1992	63	3.1	0.9	49	375
B	1 - 1993	89	0.03	0.004	30	190
	2 - 1993	196	0.3	0.03	14	100
	3 - 1996	201	1.6	0.1	15	125
	9 - 1995	277	1.1	0.1	13	120
	11 - 1992	184	2.0	0.2	15	105
C	4 - 1991	190	2.2	0.5	41	790
	4 - 1995	322	3.1	0.3	16	200
	6 - 1992	147	7.4	0.9	21	165
	7 - 1996	199	2.7	0.5	30	440
	10 - 1994	222	2.7	0.3	18	175

[a]A: systematic sampling of all forested areas in the zone.
B: systematic sampling with survey limited to wintering areas > 2.5 km^2.
C: stratified sampling with survey of A and B strata.
[b]Expressed as % of mean estimate.

TABLE 3. Deer density estimated by the double-count technique for eight aerial surveys replicated two to five times in Québec.

Survey	Replicate	Delay[a] (days)	Sighting probability of deer groups			Deer/km^2	
			Front	Rear	*m* plots	$\bar{x}$	90% confidence limits
Anticosti - Simone1988	1		0.48	0.63	20	15.6	11.5–19.7
	2	2	0.49	0.63	20	13.2	10.1–16.3
	3	4	0.55	0.60	20	12.3	8.2–16.4
	4	7	0.70	0.78	20	11.6	9.9–13.3
Anticosti - Salmon 1988	1		0.65	0.59	25	9.9	7.8–12.0
	2	2	0.53	0.67	25	8.5	6.3–10.7
	3	7	0.73	0.58	25	11.3	8.4–14.2
Anticosti - Simone 1989	1		0.61	0.49	40	8.1 AB[b]	6.1–10.1
	2	7	0.47	0.36	40	11.7 A	8.7–14.7
	3	9	0.38	0.43	40	11.5 B	8.3–14.7
Watopeka 1990	1		0.62	0.65	33	4.7 C	2.8–6.6
	2	6	0.75	0.88	28	3.9 D	1.9–5.9
	3	31	0.39	0.56	28	2.6 CDEF	1.1–4.1
	4	85	0.64	0.56	28	4.4 E	2.2–6.6
	5	86	0.43	0.55	28	4.1 F	0.9–7.3
Armstrong 1991	1		0.67	0.56	35	11.6	8.7–14.5
	2	64	0.50	0.60	38	10.9	8.0–13.8
St. Gédéon 1991	1		0.57	0.55	26	8.6	6.6–10.6
	2	59	0.24	0.29	22	6.8	2.0–11.6
	3	74	0.59	0.32	31	6.9	4.5–9.3
Island Brook 1991	1		0.85	0.75	32	12.4	9.9–14.9
	2	66	0.65	0.51	39	9.8	7.1–12.5
Témiscouata 1995	1		0.71	0.59	34	9.6 G	6.9–12.3
	2	7	0.29	0.12	33	6.6 G	2.2–11.0

[a]Number of days after the first replicate.
[b]Within each survey, pairs of means having the same letter have a difference > 30% (biologically different).

are used for deer than for Moose because deer occur at higher densities. For Moose, the plot size is 6 × 10 km (Crête et al. 1986). Therefore, total cost for a typical zone is about $43 000 for deer, as compared to some $150 000 for Moose (recalculated from Courtois et al. [1996] on a basis of $1000/hr for helicopter).

Repeatability is important as conditions may change between surveys. Although no differences were detected among eight replicated surveys when comparing CI, this procedure had low power because of small sample size and high SE (Steidl et al. 1997). Nevertheless, only three of 24 replicates overall had a difference in deer density that we considered biologically significant (> 30% within each survey) with other replicates. The delay between replicates cannot explain such differences because no more than a month separated the replicates involved within these surveys. On Anticosti in 1989, the first replicate of Simone block provided a lower density than the following two replicates. Because of thick and dense snow, deer were difficult to detect on that survey, and the observers possibly improved their skill on the second and third replicates under such conditions. In the Témiscouata wintering area, sighting probabilities of both observers were unusually poor (0.12-0.29) on the second replicate, when crusted snow was present and deer were immobile. This resulted in a low density estimate and poor precision (90% CI = 66%). Low sighting probability of the front observer (0.39) might also explain the results of the third replicate in the Watopeka wintering area, the only result that was different in that survey. The problem in two of those three surveys is related to a low sighting probability (< 0.40). The sighting probability therefore appears to be a good measure of the quality of a double-count survey. Simulations have shown the technique to be robust to unequal capture probability (Magnuson et al. 1978), unless the sighting probability is < 0.45 (Caughley and Grice 1982). Graham and Bell (1989) suggested applying double surveys only to highly visible (≥ 0.50) populations. Based on our replicated surveys, we suggest that results from the double-count technique are valid if sighting probability exceeds 0.45, but might underestimate deer densities when the sighting probability is < 0.40.

As compared to the pellet-group count technique, double-count aerial surveys gave similar estimates in five of nine surveys of wintering areas. The largest difference stems from two surveys of the Pohénégamook wintering area, where the aerial estimate is twice the pellet-group estimate. Pohénégamook has

TABLE 4. Deer population estimated by the double-count aerial survey and by the pellet-group count techniques for nine deer wintering area surveys in Québec.

Survey	Double-count aerial survey			Pellet-group count population[a]
	m plots	Population	90% confidence limits	
Armstrong 1989	25	2500	1780–3230	1770[b]
Watopeka 1990	89	860	630–1090	680[c]
Lac David 1990	60	1060	790–1320	1630[c]
La Macaza 1990	62	2230	1670–2790	2530[c]
Armstrong 1991	35	1500	1120–1870	1770[b]
St. Gédéon 1991	26	1280	970–1590	1040
Island Brook 1991	32	1090	870–1310	1190
Pohénégamook 1994	61	480	430–530	300[d]
Pohénégamook 1996	39	520	440–600	250[d]

[a]Using a defecation rate of 26 pellet-groups/day.
[b]Population estimate for winter 1990. No pellet-group count surveys were done in 1989 and 1991 but the estimates for 1988, 1990, and 1992 indicate a stable population.
[c]Pellet-group count surveys were done in 1989.
[d]Dumont et al. (1998); population estimates by the pellet-group count were modified using a defecation rate of 26 pellet groups/day.

the longest winters (>120 days) among our study areas and poor quality habitat (Dumont et al. 1998). Under such conditions and with reduced food intake, we suggest that the defecation rate might be lower than 26 pellet groups per day. In that same area, Potvin et al. (1981) conducted pellet-group counts and dead deer surveys from 1972 to 1979. Using the annual population estimate from the pellet count (defecation rate = 13 pellet groups per day) and the tallied number of dead deer, they evaluated winter mortality rates of up to 40%. With the same data, a defecation rate of 26 pellet groups per day would have lowered by half the population estimate and therefore doubled the mortality rate, which appears unrealistic. Therefore, a lower defecation rate certainly prevailed. Overall, we consider that the double-count aerial survey technique generally provides similar deer density estimates to pellet-group counts. Although the costs of both techniques are rather similar, we suggest that aerial surveys provide more reliable estimates because pellet-count evaluations require two arbitrary variables, defecation rate and deer concentration period inside the yard.

Pellet-count estimates do not provide a valid standard against which to measure accuracy of the double-count aerial survey technique. Because of plot size, an evaluation of the accuracy would require a very large enclosure (> 5 km^2) with a known population, something rarely available for logistic and budget reasons. Using marked deer with radio-collars to measure sighting probability is neither feasible with double counts as the observer would not always be able to verify if the animal seen had a collar or not. Because deer densities are high, it is not possible to find the animal when flying back, which is the usual procedure for Moose.

There are possible bias in the double-count technique. First, the two observers aboard the aircraft have almost the same vantage point, so that the sighting probabilities may be overestimated and the true deer abundance underestimated. Furthermore, some concealed animals (e.g., under dense vegetation) may have a null sighting probability (Marsh and Sinclair 1989), a factor also adding to negative bias. Overall, we consider the gradient of densities obtained in Québec by the double-count technique to be realistic. A general decrease in densities from southern to northern or eastern zones corresponds to observed winter severity and habitat quality. Anticosti Island is the only exception on that scale. Despite a boreal forest habitat, Anticosti has no predators and a low harvest rate (<10%), which explains the unusual high density at that latitude.

Management Implications

The double-count technique is reliable to survey White-Tailed Deer over medium and large areas at a reasonable cost, with great potential utility for state and provincial deer management programs. At northern latitudes, the best period is early winter when there is a uniform snow layer on the ground (≥ 10 cm). Later in winter, deer congregate in dense coniferous cover, becoming less active and more difficult to see. Summer surveys can also be conducted where snow is absent, if there is a good contrast between the deer colour and the ground, and if deciduous trees and shrubs are not too dense. New Brunswick has already successfully used the technique in winter in parts of the province (Ballard et al. 1999; Gerry Redmond personal communication).

Although it is feasible to manage deer populations by using only indirect data (e.g., harvest) and models, these techniques are not quickly sensitive to drastic change. White-Tailed Deer are becoming a nuisance animal across North America (Warren 1997). Non-hunters and conservationists might more-

easily accept deer population reductions when deer numbers are obtained by precise aerial surveys rather than through pellet-group counts or harvest based computer models. Hunters also might be more willing to increase or decrease harvests if reliable deer density figures are provided.

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Book Reviews

ZOOLOGY

Survivors in Armor: Turtles, Tortoises, and Terrapins

Orenstein, Ronald. 2001. Key Porter Books, Toronto. xi + 308 pp. Illus., $45.

With their armour of carapace and plastron, turtles are one of the most distinctive groups of organisms in the world. Yet few naturalists seem to know very much about turtles. Ronald Orenstein has set out to correct this oversight in this wonderfully fascinating and beautiful book.

In ten chapters Orenstein covers all the major topics of turtle biology and conservation. The book begins with a general introduction to the diversity of turtles and their ecological complexity. Next, a thorough analysis of turtle evolution clearly charts out the competing theories of turtle ancestry. Two chapters provide a summary of each of the families of turtles, allowing the reader to see patterns within groups of turtles. The next few chapters cover various aspects of turtle physiology, ecology, and reproduction. The book concludes with two chapters on threats to turtles: one on sea turtles and one on all other species.

Orenstein freely admits he is not a herpetologist, but he had three expert consulting editors: Jean Mortimer, Chair of the Hawksbill Task Force; Peter Pritchard, Director of the Chelonian Research Institute; and George Zug, Curator of Herpetology at the National Museum of History in Washington DC. This combination of talent has produced a book that is highly detailed in information, yet clearly written and aimed at a general audience. The book is also lavishly illustrated with colour photographs. The quality of the photos ranges from good to exceptional and they feature many of the species mentioned in the text. Although many of the species featured are from North America there are also photos of species from Asia, Australia, and South America.

The book is filled with wonderful little gems of detail that illustrate the incredible diversity of life-history strategies within this small group of organisms. For example, the Tent Tortoise (*Psammobates tentorius*) of South Africa has evolved "gutters" along the edge of the carapace. During light rains or mists, water collects on the carapace, runs into the gutters, and, by tilting its carapace forward, water runs forward and the tortoise can drink. And the Northern Long-necked Turtle (*Chelodina rugosa*) of Australia has the distinction of being the only known reptile which lays its eggs under water. The eggs are laid underground in temporary ponds, don't start developing until after the water dries up, and don't hatch until the start of the next rainy season.

Turtles face horrific threats to their existence and Orenstein does a thorough job of describing their bleak future. Great emphasis is placed on the current crisis in the trade in Asian turtles for food. Over nine million live turtles were imported into Hong Kong in 1998 alone. Approximately half of the 89 species of turtles native to Asia are considered to be endangered or threatened. North American species are not much better off with populations threatened by habit loss, traffic mortality and collecting for the pet trade.

Sea turtles have been overharvested for centuries and Orenstein illustrates this effectively with the tale of Bermuda. Green Sea Turtles were so depleted around Bermuda that the Bermuda Assembly passed laws to protect them as early as 1620. Despite such attempts it is now estimated that Green Sea Turtle populations in the Caribbean have decline by at least 99% since the time of Columbus. Orenstein also discusses other threats such as fibropapillomatosis (a mysterious disease that causes fibrous tumors), long-line fishing vessels, and shrimp trawlers. He also explores the complex political waters of the WTO (World Trade Organization) and CITES (Convention on International Trade in Endangered Species) that sea turtles have had to navigate.

Why should we care about the fate of these reptiles? As the author states in his preface, turtles "matter because it would be shameful if their long tread through 200 million years of evolutionary history should end through our negligence, our greed, and our failure to act" (page xi). This book is a celebration of the wonder of turtles and a plea for their continued survival. I hope it succeeds.

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Amphibians and Reptiles of Pennsylvania and the Northeast

By Arthur C. Hulse, C. J. McCoy, and Ellen J. Censky. 2001. Comstock Publishing Associates, a division of Cornell University Press, Ithaca. xi + 419 pp. Illus., U.S. $39.95.

In theory, this substantial volume should be the definitive guide to the 83 species of amphibians and reptiles found in the northeastern United States. It should also be a valuable resource for eastern Canadian naturalists as most of the amphibians and reptiles found in Ontario or to the east are covered in this book. Unfortunately this book falls far short of the standard expected from a university press.

The structure of the book is straightforward but thorough. The book opens with a brief introduction on the geography and climate of the area. Next a set of keys is provided for both larval amphibians and adult amphibian and reptiles. The book also includes 133 colour photos of the species covered. The photos are small (four or more per page) but there is more than one photo for many species. These additional photos are often of colour variations, eggs, or larvae. The bulk of the text is devoted to the species accounts. Accounts vary from approximately 2–4 pages in length and include a distribution map (locality dots for Pennsylvania, but just shaded for the rest of the northeastern range). Each account follows the same standard format with the following headings: description, confusing species, habitat and habits, reproduction, remarks, and distribution. The book concludes with an appendix, glossary, and literature cited. The appendix is a compilation of measurements on males and females of most species from Pennsylvania. For example, for salamanders they provide the mean (± standard error) snout-vent length and total length of males and females of each species and note whether the differences are statistically significant.

The outline for this book is thus detailed and thorough. Unfortunately, the execution leaves much to be desired. The worst of the mistakes are in the keys. Although profusely illustrated the labels sometimes are in error. For example, the illustrations of venomous vs. non-venomous snakes are switched. The key to adult salamanders has a critical typo making it impossible to get past step eight and into the plethodon salamanders. Including a key to tadpoles is wonderful, but for some reason the authors omitted three species (Pine Barrens Treefrog, Mink Frog, and Carpenter Frog) with no explanation.

The species accounts are generally fairly good as far as they go. More information could be provided on these species, but space limitations obviously had to be balanced with the amount of detail. An extra page on each species would have added almost 100 pages to the final book. There are a few factual errors. The authors state it is unknown whether Pickerel Frogs hibernate on land or in water, yet this species is known to generally hibernate under water. There are also some peculiar omissions. The Wood Turtle account fails to mention worm-stomping, surely one of the most intriguing feeding behaviours in any turtle, despite the fact that the discovery was made in Pennsylvania.

The most surprising gap in this book is any substantial treatment of amphibian decline, or conservation in general. There is no single section on the growing threats to amphibians and reptiles, only occasional references in the remarks section of the species accounts. Even these occurrences are sometimes bewildering. For example, the authors write "Although the wood turtle is not considered to be in any immediate danger in Pennsylvania, the potential for extirpation in the state does exist" (p. 214). Apparently potential extirpation from the entire state is not "immediate" danger.

In summary, while this book had the potential to be an excellent resource on amphibians and reptiles it ends up being a flawed but moderately useful book. Wait for the second edition and hope the authors pay more careful attention to detail.

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The Sibley Guide to Bird Life and Behavior

Illustrated by David Allen Sibley, edited by Chris Elphick, John B. Dunning, Jr., and David Allen Sibley. 2001. Alfred A. Knopf Inc., New York 608 pp. illus. U.S. $45

This new Sibley guide is a useful contribution to the rather limited number of volumes that seek to take the birder beyond identification to the complexities of "how birds live and what they do." It features Sibley's excellent artwork throughout, and he is one of the editors, but the actual text is the work of over 40 individual authors.

The book is divided into two broad sections. Part I, some 106 pages long, consists of five chapters on the "World of Birds", and covers subjects ranging from Flight, Form, and Function, to Behavior, Populations, and Conservation. Each chapter is well organized with the various topics discussed under a series of sub-headings, and taken together, they provide a comprehensive survey of birdlife in a concise and readable format.

Part II, and the greater bulk of the book at some

440 pages, is a survey of the bird families of North America. Each family is covered in turn, with the treatments ranging from two to 20 pages, depending on the number of species in the family. The approach mirrors Part I, with subject headings on Taxonomy, Food and Feeding, Breeding, Movements, and Conservation, and additional headings for the larger chapters. Each family account also includes a box giving a summary of "Worldwide Family Features".

Because each section has its own authors there is some unevenness in style, and some parts are heavier than others, but in general the editors have done an excellent job of producing a book that is free of jargon and easily read. I did find the odd over-generalization or misstatement, but these were few and in general the book was pleasantly error-free. There is a comprehensive index that seems to work well, and which allows the reader to follow up on any references to particular species in the text. The illustrations are well planned, and the book concludes with a glossary and a checklist of species.

Persons familiar with the introductory sections of the landmark *Handbook of the Birds of the World* series will see an immediate parallel in approach, but I know of no books on this continent's birdlife that provide this kind of broad overview. Most of the other books of this genre approach the topic from the level of the individual species — for example, *The Birder's Handbook,* by Ehrlich et al., which has been an invaluable source of concise natural history information for over a decade. The question is whether a book on families provides a new and valuable approach, or whether it is simply too general to give more than a superficial overview.

Certainly much of the treatment is necessarily quite general. But — because we naturally tend to concentrate more on the individual species than on the families they belong to — we often can overlook the broader picture. It is exactly this broader perspective that this guide now provides. This is a particularly useful approach for the average birder, who has often developed his or her knowledge and skills working with the traditional field guides, and who may have only a fragmentary understanding of the broader patterns of relationships within and between bird families. Such information can often be helpful with finding the birds in the first place and understanding them better, but it really comes into its own if the individual becomes involved in some other aspect of bird life, such as atlassing.

Its utility is certainly not confined to the newcomer. Even the experienced birder will probably find new information here — you may think you know all this stuff, but you may be surprised at how much you don't know, or have forgotten! For the veteran it forms a fast reference and a very readable summary of the current information on bird life.

All in all, this is a very worthwhile contribution to the North American bird literature. It brings together an up-to-date body of information that is not readily available in one place elsewhere, and presents it in an attractive, readily understandable form. If you want to expand your horizons beyond simply identifying your birds, this is a book to buy.

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A Birder's Guide to Metropolitan Areas of North America

Edited by Paul Lehman. 2002. American Birding Association Inc., Colorado Springs, Colorado. iv + 508 pp., illus. $US. $26.95.

I travel a fair amount for business and so I look for birding opportunities wherever I go. For some years I thought I should write a guide for people who, like me, spend a day or two in a city and then move on. Now Paul Lehman has produced such a book. He has collected a group of local experts or groups to write a chapter on 33 major North American cities (including seven Canadian cities).

This book is written in the same pattern as the other ABA/Lane guides. For each city there is a description of any good birding sites within the city and surrounding area. This account includes the most interesting species present with due reference to seasonal changes. I thought the descriptions of the birds you are likely to find were realistic. Too often I read an account of a birding "paradise" only to find that it includes twenty years worth of rarities as if they were regular visitors. This is not to say the mega-finds are not included, but they are kept in context. Clear maps and detailed instructions, including parking spots, are provided to assist the visitor in finding their way around. In addition to the information on birds there are also useful climate and travel tips, plus material on driving times and safety. The content of the book was provided by some of the most experienced and knowledgeable people in each area and reviewed by an equally impressive group of experts.

Although this is a very useful guide it is not quite what I had in mind. I was thinking of a book that would describe areas you could walk to from a downtown hotel (or at least reach with public transit or a short cab ride). This book covers not only the inner parks and shorelines but has a lot of information on areas that are one to two hours drive away.

For example, the Detroit section includes Port Huron and Calgary includes Peter Lougheed Park; both about an hour and a half drive. This is not what I think of as a "metropolitan" area, so for many of the areas mentioned you will need a car. Although the editor states this book is intended for visitors to the downtown core and those who can wander farther afield, the bias is for the mobile birder.

There are many cities missing, Victoria, British Columbia and St Johns, Newfoundland are two that come immediately to mind, as they are both places where you can easily walk to good birding areas from downtown. The biggest gap though is in the prairie and central plains region and, less surprising, there is nothing north of Calgary, Alberta. Book size is always an issue when creating a portable guide. This 33 city volume is already roughly equivalent to a *National Geographic Field Guide to Birds of North America*. It will, therefore, easily fit in your travel case. Personally, I am more likely to photocopy a few relevant pages to take with me. These I could write on, drop in the mud, and eventually discard without disturbing my original text.

Like any book of this type, it starts going out of date as soon as it is published. For example Shepard Slough near Calgary has been drained and the Crested Mynas on Wylie Street, Vancouver are down to a single pair (currently nesting). To combat this problem there are resources such as web sites, RBAs, and phone numbers to bring you up-to-date.

The concept of this book is good and in its current form will be of great value to the travelling birder. I hope that the process is continued and a second volume or edition will fill in some of the blanks. Now how do I justify a trip to Los Angeles?

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The World of the Hummingbird

By Robert Burton. 2002. Firefly Books Ltd., Willowdale, Ontario, Canada. 158 pp., illus. $40.

The philosophy of the wise prairie naturalist Isabel Priestly was that articles (or books) should be written as if two naturalists were exchanging their experiences in an informal way, yet were scientifically correct. Robert Burton is definitely that kind of naturalist and author. He is a practiced and skilled writer who is able to tell a vivid tale, underpinned by the best of scientific knowledge. In this book, his storytelling ability not only applies to the joys of seeing this extraordinary group of birds, but to scientific explanations of complex phenomena. For example, the author evidently has a keen interest in the physics of flight. His explanations of hummingbird flight are clear, straightforward and accurate and very understandable. He covers the fundamentals of colour in hummingbird feathers (or any other bird for that matter) plainly and perfectly, while retaining the magic the colours evoke.

There is much about hummingbirds that is well studied. These birds attract researchers not simply for their colourful plumage, but by their unusual behaviour and their visibility. The author has drawn from these studies to give us a glimpse into the life of these tiny birds. In addition to a general introduction and the aforementioned section on flight, the author explains the all-important relationship of these birds with flowers. The influence that flowers have on the size and shape of each species and the adaptations of the flowers to accommodate their principal agents for pollination make enticing reading. The chapter on the social behaviour I found fascinating and, for me, threw new light on the role played by the hummingbird's belligerent behaviour . Despite their minuscule size hummingbirds make some prodigious flights. As the author explains these not only follow the seasons but track the food supply as well.

The nesting biology is both surprising and engaging. Their diminutive nests are remarkable constructions that are often difficult to spot (I once spent 40 minutes pointing out a nest to a large group, and many did not see it until the female landed on it). The strategies the birds use to ensure nesting success are equally remarkable.

The author finishes with the relationship of hummingbirds to humans. I was astounded to read that in the 17th century hummingbird skins sold for £8.00 (about $2000 in today's money) and ONE dealer imported 400 000 skins in ONE year. It is amazing there are still hummingbirds left. Happily times have changed and hummingbirds get some measure of protection, and in some places considerable help.

The book is illustrated by some frame-filling, crisply focussed photographs. Given the bird's inherent twinkling brilliancy and given that they are typically feeding on a sumptuous flower these photographs are just delightful.

This is one of the best-written books I have read. It would be a wonderful gift, even if you give it to yourself.

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The Complete Encyclopedia — Antarctica and the Arctic

By D. McGonigal and L. Woodworth. Firefly Books Inc., Willowdale, Ontario. 608 pp. Illus. Cloth $59.

This is a wonderful book that captures the Antarctic experience remarkably well. It is a large-sized volume with roughly 50% of the space taken by photographs, much like a coffee table book. It also has a substantial amount of explanatory text that makes it far more than a simple picture book. While I might question the term "complete encyclopedia," the book does have a great deal of substance. For reasons that will emerge below, I think it is best to emphasize the Antarctic content first.

The book is divided into six parts. The first three parts cover the natural environment, including wildlife, climate, geology, and geography. The second half of the book deals with the various components of human interaction with the Polar Regions.

The explanations begin with a description of the current and evolutionary geology of the two poles, followed by an explanation of the climate. In particular, the various stages of sea ice formation and the birth of icebergs are described in some detail. Human influence on climate change (including the author's polite use of "burp" for the emission of methane by our cattle) together with the concerns over the ozone hole are explored in precise tones that even an American president will understand.

The geographical section describes the key features of the entire Antarctic region. Something of the history and, hence, the names of various areas along with some geological background are given. Also included, justifiably in my opinion, are the sub-Antarctic islands. Though they lie beyond the Antarctic proper, they have played a major part in the region's natural and human history.

More than half the book is devoted to Antarctic Wildlife and Exploration. As well as giving a general introduction to Antarctic ecology and the role played by krill and other marine life, the authors give detailed accounts of most of the prominent wildlife. Seals, cetaceans, and birds are treated in the same manner as a reference text such as *Birds of Canada*[1]. Penguins, as the real symbol of this continent, rate a chapter of their own. Range maps are included where appropriate.

The second major section is on Antarctic exploration. This is a thorough and well-written review of this exciting phase of human endevour. The early whalers are treated fairly for their exploration and contribution to knowledge without being judgmental on morals that existed 150 years ago. All the well-known names appear under the heading "Heroic Age"; Shackleton, Scott, Amundsen, etc. But other lesser lights like Nobu Shirase and William Filchner get an appropriate and respectable mention. As well as current photographs this section contains reproductions of original plates taken by the expedition photographers. There are some beautiful renditions of Frank Hurley's classical photos of the ill-fated Shackleton expedition of 1914.

The text is profusely illustrated with photographs that range from good to stunning, with most being at the high end of the scale. The photographs of nature are simply wonderful and they invade the non-wildlife sections of the text. Here their sole function seems to be decorative. They do not appear to relate to the text, but why should we complain about such lovely images? They are just delightful. The illustrations include a number of beautiful, clear, and accurate maps. I was impressed to see South Georgia correctly positioned. Many years ago someone produced a map where South Georgia was 1° in error and this mistake has been reproduced time and again.

Now let us look at the Arctic portion of this encyclopedia. While the material devoted specifically to the Antarctic takes up about 70 percent of the pages, the Arctic gets about 10 percent. This is an enormous disparity and it shows. In the wildlife section only seven species of birds are depicted and a number of famed Arctic residents get little or no mention. What has happened to the geese, eider, shorebirds, falcons, and pipits, not to mention the most famous species of them all, Ross's Gull? The mammal section is also very short, despite being padded by some "southerners" like Wapiti (now virtually confined to the southern Rockies). Oddly there is no photograph of Caribou, except a picture of Reindeer taken in South Georgia. The Moose shown is found a little closer to the Arctic (southern Hudson's Bay and it has been pushing northwards in Labrador), but I hardly think of it with Polar Bears and Grey Wolves. The marine mammals fare a little better, but hardly get equivalent treatment to their southern counterparts.

The section on Arctic Exploration is similarly short. It does mention the key figures such as Frobisher, Parry, Franklin, and Nansen, but there are a number of people missing. Three in particular seemed notably absent. Touching my national pride a little I missed seeing mention of Bob Bartlett of Newfoundland, Canada. Over 40 voyages and more than 200 000 miles sailing in Arctic waters should get at least an honourable mention. Captain Henry Larsen's two historical traverses of the North-west Passage in the *St. Roch* — west to east in 1942 and east to west in 1944 — is another notable Canadian achievement neglected by the authors. A further important fumble is leaving out Ralph Plaisted of Minnesota. Plaisted and three others were the first men (1968) to make an overland trip to the North Pole that has indisputable verification (by two separate US Airforce navigators using gyro-compasses). Peary and Cook's claims are far too unrealistic to be acceptable. Among the other notables not mentioned are Bylot, Sverdrup, and Papinin.

There are a few minor errors. "Ruffled" Grouse — part of an insert on cyclical food chains — is clearly a simple mistake. Making a point of calling a Yellow-billed Pintail carnivorous is a bit misleading. There are many carnivorous ducks (mergansers, goldeneye etc.); this pintail has the bizarre habit for a duck of scavenging corpses. The authors start their discussions on cormorants and then switch (correctly) to the term "shags" but without an explanation of the difference. The text on skuas does not cover the complexity and disagreement of this difficult group. Some of the photos do not have precise identifications.

This tome concludes with a section on living in the Polar Regions (mostly the Antarctic though) and some of the activities that are taking place (research, aviation, shipping, fishing, hunting, and tourism). The final entry is a full text of the Antarctic treaty and Antarctic websites.

So this magnificently illustrated book does a wonderful job on describing the Antarctic and gives a very brief introduction to the Arctic. As such it is a great resource for basic material on the Antarctic. While it is worth buying for the pictures alone, it does contain an "encyclopedic" amount of well-written information too.

[1]Birds of Canada. Revised Edition. By Earl Godfrey. 1986 National Museums of Canada Bulletin Number 203. Ottawa, Canada.

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The Complete Guide to the Birds of Europe

By L. Svensson and P. Grant (Translation by D. Christie, originally published in Swedish in 1999). 2002. Princeton University Press, Princeton and Oxford. 399 pp., illus. £25.

In 1977 the Royal Society for the Protection of Birds (RSPB) published a booklet by M. Everett & P. Hayman called *What's That Bird*[1]. This publication consisted mostly of illustration with little text. It showed birds in classical field guide format (mostly side views) and added numerous vignettes of birds flying away, in silhouette, front view and so on. From this multiplicity of images the reader got a much better idea of that quality birders call "jizz." I long wondered why this novel idea was not imitated. Now it has been copied in both North America and with this book, Europe.

In my opinion there are four development stages birders go through. The first is to identify birds by field marks, in the Peterson style. Then birders learn about habits and habitat. Next they work at identifying birds by song. Finally, the real enthusiast gains sufficient experience to use "jizz" — a combination of subtle features like relative body proportions, nature of flight, oddities of behaviour and a multitude of minute details that demand dedicated observation.

We may have to invent a new term for this kind of book. It is too large (8.5'' × 12" × 1" or 22 cm × 31 cm × 2.8 cm) to be considered a field guide. Yet it is much smaller than *Birds of the Western Palearctic*[2] and similar reference works. How about calling it a reference guide? It is similar in style to a field guide, but because of its much larger format it contains about 3.5 times more illustrations than a typical guide does. For example, for most species there are roughly six depictions per species versus three in the *National Geographic*[3] and less than two in *Peterson*[4] This allows the authors to show the different look a bird could have due to light or position or subspecies. In other words it gives a better sense of its "jizz." The main illustrations are also around 1.5 times larger than other comparable books. Moreover there is about twice as much supporting text than the typical guide. The range maps are good, but at one inch square are rather small.

The artwork, by Killian Mullarney and Dan Zetterström, is impressive. I saw some of Mullarney's work when he was still young and was struck by his skill. His partner Zetterström has a similar format and quality so the book is visually smooth. Except, that is, for one discordant note. The illustrations of the North American warblers are by Larry McQueen. Although well done they are in a different style to the rest of the book. The two main artists have contributed many excellent illustrations of other North American birds (Gulls, thrushes, shorebirds, ducks etc.) so I was surprised at their reluctance to paint the warblers too.

I thought the gull plates were very good, showing some of the best information on Common vs. Ring-billed gull and Herring vs. Ring-billed gull. There was no depiction of the pink flush on Franklin's Gull. It is one of the few texts that show the juvenile plumage of Little Gull that can be confused with Sabine's Gull – a mistake I have seen happen. Both male and female Rough-legged Hawks are shown. There is a plate dedicated to duck hybrids and a special section on the different diving techniques of scoters.

In my copy, there are a few pages where some, but not all, birds are too pale, including some geese, larks and pipits. There are some species where the colour is too intense. These include Evening Grosbeak and some owls. The female Barrow's Goldeneye beak, one of its key features, is far too dark. Virtually the entire bill is a rich golden yellow,

a mark I showed a visitor even in poor light this winter. The shapes of birds are particularly accurate. The only one I thought was too stocky was the should-be-sleek Black-browed Albatross. The Great Grey Owl shows a streaked breast with no horizontal barring. This is the *Strix nebulosa lapponica* race that will have a pale appearance to North Americans. The back of the Hawk Owl has large pale patches which mark as the nominate race *Surnia ulula ulula* and this will also look a little odd to North Americans. A few of the extreme rarities and introduced species are not illustrated.

The author's choice of English names is a bit confusing. They start by using Red-throated Loon not Diver, but go to Great Northern – not Common – Loon. They add such words as (Common) in parentheses in front of Raven, but also in front of (Black-billed) Magpie. Hoary Redpoll is called an Arctic and White–winged Crossbill is a Two-barred. The scientific names are, of course, consistent.

Overall, this is an excellent book not only for Europeans but for North Americans too. Many birds from North America are covered and covered well. For example, there is good information on separating Grey-cheeked and Swainson's thrush. As well, of course, there are numerous European species that occur here, such as Fieldfare, that get detailed treatment. It is a fine reference for all those species the two continents have in common.

References

[1]"What's That Bird." M. Everett & P. Hayman. 1977. RSPB

[2]Handbook of the Birds of Europe, the Middle East and North Africa — Birds of the Western Palearctic. S. Cramp. 1980 Oxford University Press

[3]Field Guide to the Birds of North America. National Geographic Society.

[4]A Field Guide to the Birds of Britain and Europe. R. Peterson, G. Mountfort and P. Hollum. 1954. Collins.

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The Cuban Treefrog in Florida: Life History of a Successful Colonizing Species

By Walter E. Meshaka Jr. 2001. University Press of Florida, Gainesville. xxiii + 191 pp. Illus., U.S. $69.95

The Cuban Treefrog (*Osteopilus septentrionalis*) is a hylid treefrog native to Cuba and the Bahamas. It appears to have been introduced into southern Florida early in the 20th century and by the mid-1970s its distribution was fairly continuous throughout south-central Florida. This alien invader is not alone: to date there are over 30 exotic species of amphibians and reptiles established in Florida.

The question is why are some species successful colonizers and others are not. Meshaka attempted to answer this question, with regards to the Cuban Treefrog, in his PhD dissertation, which focussed on Everglades National Park. He examined six general aspects of the Cuban Treefrog's biology that presumably affected its colonizing ability: reproduction, activity patterns, habitat affinity, diet, predators, and body size. He then examined each of these characteristics with ten ecological correlates associated with successful colonization: high fecundity, short generation time, ability to function in a wide range of physical conditions, similar habitats in native and introduced ranges, coexistence with humans, broad diet, open niche space, superior competitive ability, predator-free space, and large body size compared with its closest relatives. The Cuban Treefrog met all but one of the ecological correlates. The niche space was not open, but this did not impede its ability to colonize. Cuban Treefrogs lay many eggs, can breed at almost any time of the year in southern Florida, flourish in disturbed environments and can eat virtually anything, including many of their competitors.

Meshaka has done a lot of worthwhile, detailed work. He has dissected hundreds of Cuban Treefrogs to examine their reproductive state across the seasons, counting ovarian eggs, and identifying prey from their guts. It nonetheless makes for a slim volume that has been padded to reach even this length. For example, in one chapter he includes over 30 mediocre black-and-white photographs of Everglades National Park. Many of the photos provide before and after shots of the effects of Hurricane Andrew. This is worthwhile, but the author just doesn't know when to stop. Likewise, Meshaka puts in every conceivable figure and table he can think of including one illustrating the accumulation curve for papers published on the Cuban Treefrog from 1750 to the present. The chapter on diet reaches a crescendo with 24 figures and 29 tables. Detailed work that should definitely be in his dissertation, but one expects some sieving of material before publication. Of course that means there wouldn't be enough material for a book, but there would be two or three strong papers for publication. And given the hefty price for this book that route would have likely reached a wider audience.

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National Audubon Society Guide to Marine Mammals of the World

By P. A. Folkens, R. R. Reeves, B. S. Stewart, P. J. Clapham, and J. J. Powell. 2002. Alfred A. Knopf Publisher, New York. 527 pp., illus. U.S.$26.95.

This is another milestone publication and a wonderful and handy guide book which is full of details about the fascinating world of sea mammals. It was created by a high-caliber team of five North American authors with world-wide experience. Forget about "World-Birding"; instead, this book presents the solid foundation for "World-Whale-Watching": the world's sea mammals ("whales, dolphins, porpoises, seals and sea lions, manatees, Marine and Sea Otters, and the Polar Bear") all in one solid book. The user will agree that this "field guide" turns easily into a fascinating read.

A true highlight of this book are its 320 splendid drawings by Pieter Folkens; but the gorgeous 418 photographs, many from field research world-wide, deserve major recognition as well. Although most whale watchers will not see animals "underwater", the stunning illustrations cover sea mammals in and out of the water, and show in detail the special features of sea mammals.

A short chapter about Marine Mammal morphology explains all body features of a "sea mammal". The authors introduce topics like "What is a Marine Mammal", "Behaviour", "Reproduction", "Food and Foraging", "Status and Conservation," and "Watching Marine Mammals" (e.g., Equipment, Etiquette, and Stranded Marine Mammals). As in other field guides, such topics are 'kept on the surface'. I find the balance between information and usability in the field is well achieved.

The 120 species accounts cover much ground. They present explanations of sea mammal names, number of teeth (no formula given), species description, similar species, range and habitat, 123 distribution maps (coordinate system included), behaviour, baseline data, and status and conservation. Species morphs are covered, so are subspecies (but their scientific names are not always given). The species accounts cover measurements at birth (length and weight), maximum measurements for males and females, and life span. The World Whale Watcher will appreciate the description of distinct flippers and fins. No identification key is given, but the many zoological details might even allow identification of dead whales from beach surveys. The well-designed and structured index allows for a quick identification in the field and on a moving boat. The species accounts are structured in four major groups of marine mammals: marine fissipeds, pinnipeds, cetaceans, and sirenians. Unfortunately, a table of contents naming each individual species is missing. But the illustrated glossary is very good since it covers so many details. The list of "regional sea mammal assemblages"' is rarely found elsewhere in a field guide.

The World Whale Watcher gets really spoiled with this book due to the documentation of all sea mammals living in the Tropics, Rivers, Pelagic Oceans, Arctic, and Antarctic. The chapters about Fur Seals and Sea Lions are real beauties; the book allows the reader to compare freshwater seals like the endemic Caspian Seal and Baikal Seal (hard to confuse them in the wild though). The chapter about the 19 Beaked Whales is another gem, even showing sharp photos for many of these rare creatures.

Presenting 120 species accounts in a row might appear to be a little boring for the average reader. However, this book contributes greatly to global sea mammal conservation: one can only protect what one knows. Specifically the seal chapter emphasizes the importance of international legal frameworks like the Conservation of Antarctic Seals. The authors mention that the extinction of Gray Whales in the Atlantic is still a mystery. But on the positive side, a new species of sea mammal — the Pygmy Beaked Whale — was described as late as 1991. For completeness, the extinct Steller's Sea Cow, the Caribbean Monk Seal, and the Japanese Sea Lion are mentioned as well. The book emphasizes once more that the major threats to sea mammals stem from gillnet fishery, by-catch, aquaculture, hunting, global change, oil and gas development, and pollution. Some of these general perceived threats might suffer from "spatial biases" (locations where intense research studies were carried out).

As a realistic "World Whale Watch" test, I put this book for 15 minutes under water: it hardly survived the true "at-sea" conditions; but at least it floats and it resists water spray! Perhaps, new whale watchers might find it confusing that Killer Whales and Pilot Whales are treated as "Ocean Dolphins" and that these species cannot be found in the "regular whale" sections. The complex Ocean Dolphin chapter I find somewhat "crowded". It is too bad that none of the heavily debated population numbers mentioned in the species accounts carry any scientific references, which is crucial for the transparency of such statements in the public. It would likely be of great service to the informed user to make the distribution maps of this book digitally available. But really, that's all "peanuts" and does not subtract from the value of this splendid publication. After reading this guide, one simply wants to buy a boat and see all these unique and fascinating creatures in the wild.

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Cetacean Societies: Field Studies of Dolphins and Whales

Edited by J. Mann,, R. C. Connor, P. L. Tyack, and H. Whitehead. 2000. University of Chicago Press, Chicago. xiv + 435 pp., illus U.S. $35.

"No longer must we kill whales to study them". Instead, and as brilliantly presented in this book, innovative observational studies are nowadays carried out to learn about whales and dolphins (cetaceans). This book is indeed a cetacean landmark publication; it sets examples for many other species groups and will be of great value to the cetacean scholar as well as to the general reader interested in wildlife behaviour. However, it also applies approaches seen already in the research of apes. So is the "bible", *Primate Societies* by Smuts et al. (1987), used as a role model for this book. This approach pre-defines automatically the philosophy and conservation focus.

"Until recently, much of what we knew about cetaceans came from commercial sources such as whalers and trainers for dolphin shows". The relationship between scientists and members of the marine mammal public display community can be an uneasy one. Here we see a book based on many years of innovative field studies of wild populations. It is devoted to Ken Norris, a forefather of cetacean research. Thirteen world-wide renowned authors contributed to this volume, most of them are US-based and US-funded. The presented cetacean studies come from major cetacean study locations in the world, such as Sarasota (Florida/U.S.), Shark Bay (Western Australia), Galapagos Islands, Moray Firth (Scotland), Southwest Canada, Eastern Canada, and others.

The book is conveniently divided into three parts: (i) History and Methods, (ii) Four Species (Bottlenose Dolphin, Killer Whale, Sperm Whale and Humpback Whale), (iii) Comparative Studies, Theory, and Conservation. The Appendix is very interesting as well and deals with phylogeny and taxonomy of cetaceans. Very helpful for the reader is also the subject index and the citation index, which stimulates extensive use of the strong 57 page (!) reference section.

The book makes a stark claim for a science that is question-focused and not only taxon focused. *"Whales and dolphins are long-lived, reproduce slowly, and spend most of their lives below the water's surface"*. Therefore, they are very hard to study. This book helps to overcome this problem by devoting a great chapter to all major (boat-based) sampling approaches used in behavioural studies of cetacean societies such as Focal Sampling, Scan Sampling, Rare Events, etc. In addition, relevant field sampling issues are outlined in detail in order to assure valid inferences from field observations.

The scholar of cetaceans will appreciate as well the other specific and splendid chapters allowing for great information, such as the History of Studying Cetacean Societies, Identification by Photo, Tagging, Accoustic and Genetics. Of interest is also the topic about John Lilly and the "myths" that he created in the public mind. Once more, the Killer Whales of British Columbia, residents and transients, get covered in full length. Right Whale studies are not directly included, but often referred to.

"Research on cetacean societies is in its infancy compared with that on primates, carnivores, or ungulates". All relevant subjects currently discussed in the literature for wildlife societies are presented in this book. It deals with such 'hot topics' like fission-fusion, migration, tool use, vocal learning, benefits of group living (mutualism, altruism, cooperation), roving males, mating strategies, Humpback lecks, parental investment, sperm competition, infanticide, philopatry, gender relationships (male-male, female-female and male-female), gambits of being in a group, communication (tactile, electric, chemical, communication, visual and acoustic), parasite load in Humpback whales, and effects of Global Change.

Cetacean Societies is clearly an outstanding book in the field of behaviour studies, but, at the same time, it is lacking the presentation of real field datasets. The book primarily presents summarized results rather than any raw data (no relevant databases are reported, nor where and how they could be accessed for the public, e.g. via www). However, important (female) cetacean data on life-history, demography and many other subjects are compiled in over 20 tables; e.g., studies on travel speed. In addition, many fascinating photos taken from field work are presented in the 16 colour plates and 93 half-tones; 41 line drawings are included to show graphs and to visualize concepts.

As it may not be missing in any popular book dealing with cetaceans (but not the prime focus of this book) interesting chapters about Present Exploitation, Conservation and Whaling are included. These chapters point out that Aboriginals overhunt cetaceans in some locations in Canada. Whaling was developed from a fisheries mentality; so it was based on pure exploitation without considerations of a sound sustainability. No wonder that according to some sources up to 95% of the Humpback pre-exploitation population was eliminated. Japan's Striped Dolphin culls appear not to be sustainable either. Rather than cetaceans competing with fisheries, there can be absolutely no doubt that *"...cetaceans are more threatened by fisheries than the reverse"*.

The IWC (International Whaling Commission), a major player when it comes to cetacean conservation and research, gets only mentioned in brief detail. But the book cites that *"whale-watching around the world was estimated to be about 500 Million US$ in*

1994, roughly equivalent to 25,000 minke whale carcasses". The authors report that the effects of Whale Watching tourism on Killer Whales and others are unclear and still deserve more research.

The reader will find the overview table about cetaceans' conservation status and IUCN categories of great value. By-catch, habitat degradation and hunting are among the 16 prime threats for the conservation of cetaceans. The hot subject of 'by-catch' is not covered in much detail, but at least it is mentioned. Dams in rivers can interrupt and fragment sea mammal populations. Military exercises and industrial blastings; e.g., from oil explorations, are well known to be harmful as well.

"Until quite recently, oceans and even rivers, were perceived as almost infinite sinks that could absorb human waste with no impact on humans and little harm to the environment." How true. The MARPOL convention is supposed to fight marine pollution caused for instance by plastic, chemicals, oil or sewage (still, none of the coastal Canadian cities have a sewage system worth mentioning). The book emphasizes nicely that habitat degradation is the major component threatening the entire marine ecosystem (two thirds of the world) and that there are no administrative and national boundaries to pollution, nor to whales (animals move beyond borders and don't care about national and administrative units). The authors present a chapter on Conservation, Protection and Science which shows how scientists can contribute to this important task.

Besides giving a perfect overview and summary about current cetacean research topics, this book also shows what still needs to be researched. For instance, the book points out that nighttime research on killer whales does not exist. Behaviour approaches to systematics and taxonomy could be useful as well; so could be many aspects of behaviour-based predator-prey studies.

For my personal taste, too many of the questions asked and addressed in this book deal with "investment" and energy effort, somehow resembling pure money and banking issues, and making cost and egoistic gain considerations rule. Our behaviour research is ill-fated if only the bank/money approach, which humans face in their daily life nowadays, gets completely transposed on animals and behaviour interpretation; is that all what the science of animal behaviour currently can offer? It simply presents a limited view, and a plain copy of approaches applied to monkeys, and used earlier by Nobel-prize winning Gary Becker *'The economic approach to human behaviour'*.

Unfortunately, results and contributions from "scientific whaling" are not included in this book. Might be there are none; time will tell. Proceeds from this affordable volume go towards a fund to support graduate students on behaviour studies. This milestone reference is a grace to review and to read. Every naturalist and wildlife scientist should have it in her/his bookshelf.

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BOTANY

Lichens of North America

By Irwin M. Brodo, Sylvia Duran Sharnoff, and Stephen Sharnoff. 2001. Yale University Press, New Haven. 795 pp., illus. U.S.$69.95

Exquisite, aesthetically pleasing, wonderful, breath-taking, and magnificent barely describe the 32 full-page color pictures and nearly 900 hundred smaller ones in this book. Although they alone are worth the price, there is much more in this book. A total of 804 species are illustrated plus 250 other common North American lichens are included in the keys. These species represent about 30% of the lichens in North America.

The book has two major parts. "About the Lichens" occupies the initial 113 pages, and is composed of 14 chapters that enumerate lichen features, biology, including discussion of the symbiotic relationship between fungi and algae that make the lichens, colors, chemistry, habitats, distribution, and classification. Additional chapters treat lichens and people (food, clothing, dyes, perfumes, medicines and poisons, human impact on lichens, and much more), environmental monitoring with lichens, collecting and studying lichens, and how to use this book to name a lichen. The text is supplemented with photographs and drawings to illustrate salient points. The writing is careful and deliberate, so it does not scare off newcomers to the lichens. Concepts, features, and methods are explained simply but in detail. As with any specialized area there is terminology to be grasped. Words that may not be familiar to naturalists are explained in the text where they first appear and the glossary is also an aid to understanding terms by giving a description and often a reference to a figure.

"Guide to the Lichens" begins with a 27-page key to the identification of lichen genera and major groups. The use of a "key" is explained in chapter 14. The largest part of the book is a chapter, of 604 pages, titled "Description, illustrations, keys to species, and maps". The lichens are arranged alphabetically by genus. Thus if you know the name of the lichen it is easy to find its description. I like the alphabetical arrangement but others would prefer a grouping of similar types (i.e., all the orange species together or all the foliose species grouped), such groupings are used in the keys.

The treatment of each lichen is composed of several parts. In addition to the color photograph, there is the scientific name and, for many, a common name. The essential features, concentrating on the macro characters, of the lichen are enumerated as is the habitat, but habitat comments are brief, probably due to space limitations. For example, *Solorina crocea* in south central British Columbia is common in dry lodgepole pine forests on sandy soil, whereas the text states "usually in moist spots ... or seepage areas in arctic or alpine sites." The geographic distribution of each species is shown on a map.

Maps fascinate me. And they convey a considerable amount of information. The maps quickly tell the user whether the lichen is found in one's neighborhood. Disjunct distributions can pose intriguing questions. Why does *Parmotrema stuppeum* occur only in two areas that have little apparent similarity, the Appalachian Mountains and a narrow band along coastal California? Current distributions can reflect earlier phenomena. *Umbilicaria caroliniana*'s occurrence in only two Ice Age refugia, in the southern Appalachians, and northern Alaska and the Yukon, suggests it was widespread in pre-Ice Age times. Other species, like *Peltigera aphthosa*, are widespread and their distribution may reflect its ability to compete effectively with other plants.

Reviewers routinely trumpet the glories of the subject but they should also aid the users by indicating difficulties. There is little to complain about in *Lichens of North America*, and then the items are quite minor and do not distract from the quality and usefulness of the volume. When I first opened the book, I was struck by the beauty of some full-page and smaller photographs (for example, pages ii–xvi, 114, 116) and wondered which lichen I was admiring for these pictures were not labeled. The Cup Fungus (page 4) although labeled *Aleuria aurantia* has the morphology and habitat of *Sowerbella rhenana*. The distribution maps show all of Canada and the United States, except Hawaii. Most are useful, but lichens of restricted distribution are uncertainly discernable on the map (e.g., *Lecanora phryganitis* and *Niebla combeoides*). For these species arrows indicating their location or a restricted map (i.e., only of the southwest) would have been more informative. Figure 533 is slightly out of focus in my copy of the book.

Brodo has had a long association with The Ottawa Field-Naturalists' Club and its journal *The Canadian Field-Naturalist*. The OFNC can be proud of its support of the publication of *Lichens of North America*. And the other benefactors are to be thanked for foresight in supporting this project. One direct result of their participation is the high quality of the printing and binding and the book's relatively low price!

This book is the end product of an enormous project that took years of devotion to complete. Brodo writes (page xx) "the road to a finished manuscript was a rocky one,..." And one rock, reported by colleagues in Ottawa, was when managers at Canadian Museum of Nature, where Brodo spent most of his career, at one period near its completion prohibited work on the project. Brodo persevered at home during evenings and weekends; however, for support at the end, the title page graciously states, "published in collaboration with the Canadian Museum of Nature," and the CMN is also fairly acknowledged for its career support of Brodo's fieldwork and travel.

In summary, the book is highly recommended. The style of writing, the superb photographs, and the reasonable cost are unbeatable. A glimpse at this book should be sufficient to convince naturalists, ecologists, and others to get involved with this fascinating group of organisms. Some of the photographs in this book can be seen at www.lichen.com where one can also find more background on lichens, the preparation of the book, and the authors and their interests. Regrettably, Sylvia Sharnoff did not live to see the final publication.

J. GINNS

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MISCELLANEOUS

Life in the Treetops: Adventures of a Woman in Field Biology

By Margaret D. Lowman. 1999. Yale University Press, New Haven. xvi + 219 pp., illus. U.S. $27.50.

During the past two decades an increasing number of books, essay collections, biographies, and autobiographies have dealt with the lives, successes, and tribulation of women scientists. Most have focussed on women in the laboratory sciences, and only a few detailed the challenges women faced when undertaking fieldwork. Margaret Lowman's autobiography takes us in a different direction — upwards to the canopies of Australian, American, and African forests. In addition to its scientific aspects, this autobiography also presents a vivid picture of gender relations in the Australian outback.

As readers of the *Canadian Field-Naturalist* know, field research does not follow office hours. Biologists in the field do not work seven hours per day, five days a week with well defined rest periods and vacation times. Birds, plants, butterflies and other organisms have life cycles that do not conform to human biology and late twentieth century lifestyles. The exigencies of fieldwork do not match the rhythms of marriage and parenthood.

Life in the Treetops provides a lively personal account of the successes and setbacks of an American woman field biologist on three different continents. Born and educated in New England, Meg Lowman enrolled in graduate school in Scotland, completed her Master's degree on "the seasonality of highland birch trees" (page 10) and, influenced by her advisor's interest and enthusiasm, decided to do her doctoral research on the tropical rain forest. She chose Australia because it was both "English speaking...[and its] forests remained some of the least studied in the world" (page 11). With a scholarship from the University of Sydney botany department she soon enjoyed the scientific opportunities provided by this continent's forest ecosystems, but was unaware of the antiquated attitudes to women and conservation awaiting her.

The author's account of her scientific fieldwork in the treetops is both fascinating and amusing. She provides sufficient information for the uninitiated to understand the scientific questions she had asked and her varied methods of canopy research. She does not minimize the dangers, inconveniences, and difficulties of this sort of research for any one, particularly for a woman. Climbing to the canopy level using a rope, or being lifted to the treetops by a cherry picker, a construction crane, or a hot air balloon equipped with a canopy sled (towed under the balloon), is not for the fainthearted. Neither is building and using a canopy walkway. And these were only the technical challenges than enabled Meg Lowman, her colleagues, students, and friends to get to their field sites. Inclement weather, insect pests, poisonous snakes, and frightened Brush Turkeys were all parts of the environments she studied. Her various projects included the "growth patterns on rain forest leaves," studies "of insect herbivores in action," "plant-insect relationship," "dieback" of trees which led to challenges in applied ecology, as well as "seedling lottery" at ground level (page 94).

Accounts of the author's personal life are well integrated into the book. We learn about her attempts to juggle the roles of scientist, wife, mother, and homemaker in a social environment that did not validate or even understand her scientific interests and aspirations. This part of her story is not unusual, but is rarely documented. Women scientists of earlier periods, with the exception of Margaret Morse Nice, did not disclose personal relationships and private stumbling blocks that often delayed, slowed down, or even prohibited their scientific activities. We rarely read about taking infants in diapers into the field, disapproving mothers-in-law, or a restrictive environment that would prompt a scientist to read the *Journal of Ecology* "wedged between the pages of ... *Women's Weekly*" (page 103).

Throughout her studies and professional life Meg Lowman was encouraged and supported by her parents, teachers, advisors, and colleagues. She missed having a female mentor in Australia and did not seem to meet women botanists. While the University of Sydney may not have employed women in the biology department at the time, there were many women botanists and other scientists in Australia. Among them was Gretna Weste of the University of Melbourne who also studied dieback of the native forest and grappled with issues of motherhood and scientific research a generation earlier. Clearly, Meg Lowman was not yet part of the "intellectual spiderweb...that interconnects" scientists (page 136). In time, as an Australian researcher, teacher at Williams College in the U.S. and, since 1992, Director of research and conservation at the Marie Selby Botanical Gardens in Sarasota, Florida, she developed her own worldwide network of scientists.

This well written and delightfully illustrated book ought be read by seasoned and aspiring scientists alike, as well as the general public. It should be on the bookshelves of public libraries, high schools, community colleges, and universities. I hope that instructors in biology, history, and women's studies will take note of this slim but important volume and use it in their classes. I know that I will.

MARIANNE GOSZTONYI AINLEY

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Victorian Sensations: The Extraordinary Publication, Reception, and Secret Authorship of *Vestiges of the Natural History of Creation*

By James A. Secord. 2000. The University of Chicago Press, Chicago. 624 pp., illus. U.S.$35.

Should we be curious, after 150 years, about a little book titled *Vestiges of the Natural History of Creation*? Originally published in 1844, 15 years before Charles Darwin's *On the Origin of Species*, it prefigured the latter by popularizing the idea of evolution. Yet, why is it of any importance? Is it the fact that it was one of the early works to attempt to reach the general reading public rather than the more scientific elite; the fact that it was anonymously written; or is it the time and place it was published in conjunction with the political, social, or religious views of the day? James A. Secord, editor of the recently reprinted version of *Vestiges* (University of Chicago Press, Chicago, 1994) asks these questions.

I found this work wonderful if only for the fact that unlike the few other history-of-the-book projects, *Victorian Sensations* puts *Vestiges* in a multitude of contexts. Seemingly unrelated, they all interconnected in skeletal form with each other. And not just the obvious social, political, or religious arenas, but even with the art of making the book, the marketability from an author and publisher's point of view. Reaching a broader audience without appearing as a ragish tome was a major concern. The author of the scandalous work, a work that combined all manners of science, was publisher Robert Chambers (1802–1871). But to avoid any link to his good, prosperous name, his manuscript was issued with another publisher. Through a third party, both author and publisher masterminded the physical publication (and the numerous editions to follow), and even selected some of the reviewers.

The work contained snippets from many scientific disciplines and was formulated for the general reader in a kind yet somehow authoritative manner. From the formation of the solar system, the fossil record, to humanity, all under the guiding principle of some sort of evolutionary ideology. Conveying such a broad scientific spectrum, especially when many of these sciences were still in their infancy, was unattainable and thus not without errors. This provided much fuel to the cynical, put-off reviewers and many of the general public. As one scientist wrote, "It is humiliating to think that a work of such flimsy pretensions should have obtained so much consideration, because it proves how little the intelligent public are aware of the real progress of science" (page 212). But it placed evolutionary thinking in the public consciousness like it never before had.

Even if we can't fathom the reasoning behind the historic place of *Vestiges*, we surely must understand, or at least appreciated what it did for Charles Darwin (1809–1882). For Darwin, it was not the contents of the book that mattered, but the manner in which the public and professional reader received it. As Secord notes, "Reading reactions to *Vestiges* became a way [for Darwin] of imagining the reception of his own, unpublished essay" (page 431). Secord goes on to substantiate his claim that though culture and society has raised Darwin's stature above all but a few in the scientific arena, as no one would disclaim the impact of *The Origin of Species*, the danger of supporting the mythology the "Darwinian" Revolution can be rather myopic. To the general reader "It obliterates decades of [unheralded] labor by theologians, technicians, printers, editors, and other researchers, whose work has made evolutionary debate so significant during the past two centuries" (page 518). Works like *Vestiges*.

The reflective nature of *Victorian Sensations*, the broad spectrum of its contexts, and the resources upon which it is supported are commendable. And for those who dismiss the idea of a work's place in time, its construction, and mode of dissemination, this title is definitely worth a look.

TIM T. TOKARYK

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Northern Wild, Best Contemporary Canadian Nature Writing

Edited by David R. Boyd. 2001. Greystone Books, Douglas & McIntyre, Vancouver. 278 pp. $22.95.

Someone has finally done it. David R. Boyd, a Senior Associate with the Eco-Research Chair in Environmental Law and Policy, University of Victoria, has put together one of the surprisingly few anthologies of nature writing by Canadians — in contrast to the scores of U.S. nature writing anthologies published over the years.

Northern Wild, an attempt to fill that void, includes a wide variety of contemporary texts on topics as diverse as slugs, berry patches, Inuit navigation, home, bugs, the prairie landscape, fishing, and more (in fact, I'd wager that the editor is a fisherman, since three of the 20 texts are definitely about fishing). They range from shorter to longer, lighter to heavier, more personal to more scientific, more humorous to more serious pieces — by authors both lesser- and better-known.

Different as the essays are, they all share, as Boyd writes in his introduction, "something that we all enjoy as children but tend to lose as we grow up" – a sense of wonder.

It would be best to let some of the writers speak for themselves.

John B. Theberge experiences wonder and truth in the gaze of a wolf waking from tranquilization: "She held her gaze for a full minute, two minutes, an eternity. Wolf — human — each searching for meaning in the eyes of the other. Eyes so alike — iris, pupil, cornea, lens, size, musculature, movement. But eyes so different, reflecting two different social orders that began diverging, like two continents drifting apart, hundreds of thousands of years ago."

Beth Powning finds wonder and peace in her own home: "The comfortable, homey chirp of swallows and the snipes' mournful, swooping wing-whistle are the sounds of early morning, familiar as water filling a kettle ... I smell the dry-wood, old farmhouse smell of wood smoke and mice; and daisies, their bitter scent riding a dancing breeze ... I can't imagine ever leaving this place."

Des Kennedy shares the wonder and fascination of a slug crawling on his hand: "After a few moments of frightened withdrawal, its head emerged, the slender optic tentacles extending like time-lapse flowers. As it began to sense the world around it, one — then both — of its smaller tentacles touched the surface of my skin delicately. I watched the animal apply its pedal gland to my palm. Attaching a silvery ribbon of mucus to my skin, it slipped forward — a cold, smooth softness on my hand."

Heather Menzies feels wonder and meaning in the company of a pine she helped plant as a child: "Around me, shadows drift up like root hairs seeking passage. A breeze whiffles the upper branches, light as surf bubbles caressing a shore. I sit on the moss, enveloped by these trees I helped grow into this ground over so many years. They're in my blood now. I feel them."

That's only a brief sampling of the fine writing and diversity of topics represented in *Northern Wild*. It's a delightful and meaningful read.

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Cheltenham in Antarctica: The Life of Edward Wilson

By D. Wilson and D. Elder. 2002. Reardon Publishing, Cheltenham, England. 143 pp., illus. £9.99.

Edward Adrian Wilson was born into Victorian comfort and anonymity. He died in appalling need and with international acclaim. This remarkable man achieved more in his short life than most of us could in three lifetimes.

As a teenager I read the accounts of Scott's Antarctic expeditions, which included Wilson, and *compared* them to Shackleton. I decided that Scott fared poorly when compared to Shackleton. Scott was part of the gentry and followed the British class system. Shackleton was a team player. Scott died, as did many of his crew. Shackleton lived and no man under his direct command ever died. I always felt it was unfair that Scott's men were more famous heroes in their day than Shackleton's group. To me Scott's efforts missed the mark because he did not take common-sense advice, whereas Shackleton was a success. I have softened this stance over the years, as I understood more about the contribution made to science by Scott's team.

Despite my unfriendly view of Scott I have always been a fan of Wilson. After all he was the naturalist and artist. True, his books have a "jolly hockey sticks" flavour that comes from his privileged upbringing. Yet he did so many interesting things.

This new biography chronicles the entire life and times of this extraordinary man. The authors, Wilson (a relative) and Elder, have put together a smooth flowing narrative that captures the nature of Ted Wilson's spirit as well as his history. Some biographers include so many quotes of their subject's own writings that the rhythm of the text is destroyed. These authors have used Wilson's quotes but have done so with discretion. The quotes add extra understanding of Wilson's character without being disruptive.

For a book of its size — it is as big as a *Reader's Digest* magazine — it has a large number of illustrations. Many of these are black-and-white family and expedition photographs. In addition there are a number of colour reproductions of Wilson's artwork. Remarkably some of these date back to his childhood, so you can see his progress to a full-fledged Victorian nature artist. A number of the watercolours are in colour. As well as being delightful paintings many have a historical significance too.

I have long been puzzled by Wilson's death. The classic version is the he, Scott and Bowers were trapped in their tent by a 10-day blizzard and died of starvation. But Wilson, with Cherry-Garrard and Bowers, made a 5-week trek to an Emperor Penguin nesting colony in the middle of winter. This journey was made under appalling conditions (read *The Worst Journey in the World* by Apsley Cherry-Garrard) and they all survived. How then could these seasoned travelers, who had braved blizzards before, wait for death when salvation was only 11 miles away? Recently I read that Scott had allowed 4300 calories per day, with more protein than fat. Recent studies have shown a person can in a severely cold

climate burn 11 000 calories per day, and needs more fat than protein. These men had been starving for weeks, and starvation affects the brain's logic as well as the body. Maybe they were disoriented and confused. A second intriguing theory notes that there is no other record of a 10-day blizzard in this region. The longest was four days and this fits with the physics of the terrain. Did Wilson tell Scott, who was suffering badly — probably dying — from frostbite, that there was a blizzard so he would not know they had chosen to stay with him even though it meant their own death? This would fit with Wilson's character and deeply held principles.

A most unusual addition to this biography is a guide to town and country walks in Wilson's home neighbourhood. These direct the reader to the locations Wilson knew and visited, and to locations of historical significance. This is a clever and charming bonus.

This is a delightful book, recounting the life of a most remarkable man in an extraordinary period of history. His work had a profound impact on science; something that is often forgotten in the face of his heroic death. But there is something else about him and so perhaps the best note to end with is that his contemporaries said, "everybody loved him." After reading this book, I am sure I would have too.

ROY JOHN

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Addenda: Just as I was finishing this review I discovered that Random House has published *Cherry: A Life of Apsley Cherry-Garrard*, by Sara Wheeler (See paragraph six above). After years of anonymity there is suddenly a wonderful revival of interest in the golden age of Antarctic exploration.

News and Comment

Canadian Species at Risk May 2002

Issued by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC), the list is 34 pages containing: About COSEWIC, (mandate, membership, definitions); — Summary Tables (COSEWIC species at risk, not at risk, and data deficient; results of May 2002 COSEWIC meeting), COSEWIC Lists (Explanation of symbols, Geographical occurrence and abbreviations; List 1 Species designated in the five "risk" categories, List 2. Species examined and designated in the NOT AT RISK category; List 3 Species examined and designated in the DATA DEFICIENT category) — Record of Status Re-examinations — List of name changes — COSEWIC Species Specialist and Aboriginal Traditional Knowledge Subcommittee Contacts (2002-2003).

It is available from COSEWIC Secretariat, c/o Canadian Wildlife Service, Environment Canada, Ottawa, Ontario K1A 0H3. See Web site: http://www.cosewic.gc.ca

Froglog: Newsletter of the Declining Amphibian Populations Task Force (51, 52)

Number 51, June 2002. Contents: The DAPTF in Africa (Tim Halliday) Chytridiomycosis Survey in South Africa (Che Weidon); Amphibian Faunal Diversity and Conservation Status in The Niger Delta Basin (Southern Nigeria): A Update (Godfrey C. Akani and Luca Luiselli); Amphibian Research in Myanmar (Guin Wogan and George Zug); South Asian Amphibian CAMP; Froglog Shorts; Publications of Interest.

Number 52, August 2002. Contents: Northern red-legged frpgs and emdocrine disrupting compounds (EDCs) (James B. Bettaso, Hartwell H. Welsh, Jr., and Brent D. Palmer; Monitoring amphibians and reptiles along the Drava River (Tibor Kovacs); South Asian Amphibian Workshops: Executive Summary; Froglog Shorts; Publications of Interest.

Froglog is the bi-monthly newslett;er of the Declining Amphibian Populations Task Force of The World Conservation Union (IUCN)/Species Survival Commission (SSC) and is supported by The Open University, The World Congress of Herpetology, and Harvard University. The newsletter is Edited by John W. Wilkinson, Department of Biological Sciences, The Open University, Walton Hall, Milton Keynes, MK7 6AA, United Kingdom; e-mail: daptf@open.ac.uk. Funding for *Froglog* is underwritten by the Detroit Zoological Institute, P. O. Box 39, Michigan 48068-0039, USA.

Marine Turtle Newsletter (97)

July 2002. Contents: Articles: Cold Stunned Loggerhead Turtles in South Adriatic Sea; Use of Pop-Up Satellite Archival Tags to Quantify Mortality of Marine Turtles Incidentally Captured in Longline Fishing Gear; Satellite Tracking of Post-Nesting Movements of Green Turtles *Chelonia mydas* from the Gangkou Sea Turtle National Nature Reserve, China, 2001; NOTES: Happenstance or Design: An Unusual Association between a Sea Turtle, Octocoral and Barnacle; Apparent Beach Basking of an Atlantic Green Turtle (*Chelonia mydas*) at Dry Tortugas National Park, Florida; A Record of the Northernmost Verified Leatherback Sea Turtle Nesting Event on the East Coast of the USA; Leatherback Turtles in the Mid-South Atlantic Waters; MEETING REPORTS; BOOK REVIEW; ANNOUNCEMENTS; NEWS & LEGAL BRIEFS; RECENT PUBLICATIONS.

The Marine Turtle Newsletter is edited by Brendan J. Godley and Annette C. Broderick, Marine Turtle Research Group, School of Biological Sciences, University of Wales, Swansea, SA2 8PP Wales, United Kingdom; e-mail MTN@swan.ac.uk; Fax +44 1792 295447. Subscriptions to the MTN and donations towards the production of MTN and its Spanish edition NTM [Noticiero de Tortugas Marinas] should be sent to Marine Turtle Newsletter c/o Chelonian Research Foundation, 168 Goodrich Street, Lunenburg, Massachusetts 01462 USA; e-mail RhodinCRF@aol.com; fax + 1 978 582 6279. MTN website is: <http://www.seaturtle.org/mtn/>.

Point Pelee Natural History News 2(2)

The summer 2002 issue contains: ARTICLES: The Tiger Beetles (Cincindelidae) of Point Pelee National Park, Ontario (Stephen A. Marshall) — Noteworthy Bird Records: March to May 2002 (Alan Wormington) — Chuck-will's-widow: Second Record for Point Pelee, Third for Ontario (Robert Curry) — In Search of a Chuck-will's-widow Nest (George D. Bryant) — Chuck-will's-widow: A Nest is Found! (Alan Wormington) — The Decline of Grassland Birds: Some Insights and Comments (Alan Wormington) — IN THE FIELD — NEWS AND ANNOUNCEMENTS — UPCOMING EVENTS AND OUTINGS.

This newsletter for Point Pelee National Park, Ontario, is edited by Alan Wormington (e-mail: wormington»@juno.com). Editorial Assistants are M. Lea Martell and Matthew J. Smith. The web site is www.wincom.net/~fopp/Natural_History_News.htm. Subscription rates are Canada: CAN $15 (one year) or $30 (two years); International: US $15 (one year) or $30 (two years). Send payment (and e-mail address, optional) to The Friends of Point Pelee, 1118 Point Pelee Drive, Leamington, Ontario N8H 3V4 Canada. Issues are mailed in March, June, September, and December, and back issues are available for $15 per Volume/ $5 per issue (postage paid).

Recovery: An Endangered Species Newsletter (21) June 2002

This issue contains: recovery highlights: New project, Restoring habitat, Conserving frogs; profile: Biologist champions ecosystem recovery [Marilyn Fuchs] (David Wylynko); NEWS BITES: Custom-designing recovery; Conserving shrike habitat; Protecting a Quebec plant; Butterflies at risk; COSEWIC Update; CITES Update; RENEW Update; ESRF update; FIELD NOTES: Program asisits reptiles at risk; Monitoring whales; Falcon a celebrity; ANNOUNCEMENTS: Awards; New publications; Upcoming event; Site seeing; FEATURED SPECIES: Recovering the Barn Owl (Bernt Solymar). Contact: Recovery, Canadian Wildlife Service, Environment Canada, Ottawa, Ontario K1A 0H3. Web site: www.cws-scf.ec.gc/recovery/archive.html

Minutes of the 123rd Annual Business Meeting of The Ottawa Field-Naturalists' Club, 8 January 2002

Place and time: Victoria Memorial Building, Canadian Museum of Nature, Ottawa, Ontario, at 7:30 pm.
Chairperson: Eleanor Zurbrigg, President.
Attendance: Thirty persons attended the meeting.

Attendees spent the first half-hour reviewing the minutes of the previous meeting, the Treasurer's report and the Report of Council. The meeting was called to order at 8:00 pm.

1. Minutes of the Previous Meeting

It was moved by Dave Moore and seconded by Fenja Brodo, that the minutes be accepted as amended. (Motion Carried)

2. Business Arising from the Minutes

There was no business arising from the minutes.

3. Communications Relating to the Annual Business Meeting

There were no communications relating to the Annual Business Meeting.

4. Treasurer's Report

Frank Pope reviewed the financial report for the year ending September 30, 2001, noting that the Club's net assets had increased by $37,584. Most of this increase was the result of a surplus of $25,895 in the fund allocated for the CFN. This is due to falling behind in the publishing schedule as well as not having to purchase paper for the CFN this fiscal year.

Moved by Frank Pope and seconded by Roy John that the Financial Report be accepted.

(Motion Carried)

5. Committee Reports

Eleanor Zurbrigg introduced each of the Committee reports and a representative of the appropriate Committee and asked for questions and comments. Amendments were made to the reports of the Birds, Computer and Finance Committees.

Dave Moore asked if we had received any feedback about the materials that had been supplied for the presentation by Tom Bearss to the Trinidad Naturalists' group. Eleanor Zurbrigg said that we had heard that it had gone well. Frank Pope asked if we still received their annual report. No one was certain of this, but we do still get their newsletters.

Moved by Dave Hobden, seconded by Bev McBride, that the reports as amended be accepted.

(Motion Carried)

6. Nomination of the Auditor

Moved by Frank Pope, seconded by Roy John, that Janet Gehr continue as Auditor for another year.

(Motion Carried)

7. Report of the Nominating Committee

The Committee recommended the following list of candidates for the 2001 Council (new members are indicated by an asterisk)

President:	Eleanor Zurbrigg
Vice-President:	Roy John
Vice-President:	Gary McNulty
Recording Secretary:	Ken Allison
Treasurer:	Frank Pope

Other Members	
Irwin Brodo	Rod Bedford
Bev McBride	Bill Cody
Bob Roach	Francis Cook
Stan Rosenbaum	Karen McLachlan-Hamilton
John Cameron	Dave Moore
Roy John	Charlie Clifford*
Peter Goddard*	Kathy Conlan*
Louise Schwartz*	Diane Holmes*
David Hobden	Diane Lepage*
Barbara Gaertner	
Dave Smythe	

Four members of the 2001 Council decided not to stand for re-election: Tony Halliday, Terry Higgins, Rita Morbia, and Fenja Brodo. Colin Gaskell thanked these members for their contribution to the Club.

Moved by Colin Gaskell, seconded by Irwin Brodo, that the list of nominations for the 2001 Council be accepted.

(Motion Carried)

8. New Business

Fenja Brodo would like to see more articles from the committees in T&L. She feels that this would generate more interest in committees.

Ernie Brodo is looking for new ideas for the Soirée. He feels that interest and attendance are declining. Pearl Peterkin responded that a group of public relations students from Carleton University have produced a communication plan for the club. One of their suggestions was to remodel the Soirée.

Ernie also stated that natural history education needs increased visibility in our community. As a

club we need to help generate more interest among young people. One suggestion was to provide an education award for teachers who showed outstanding achievement in the area of natural history education.

Pearl Peterkin suggested it is time to change the award for the Science Fair. There was considerable discussion about this topic. Pearl ended the discussion by stating that any changes would now have to wait for 2003.

Ernie Brodo suggested that we should attend teachers' professional development days to offer our resources to strengthen natural history education. Frank Pope noted that this is being done, but that there has been very little concrete response in the end. Ruth Allison pointed out that any material would have to be targeted to the curriculum. Frank said that the FON provides this sort of targeted resources. Gary McNulty suggested that club members get involved in presenting natural history subjects to young people. Dave Hobden asked if we could use the club website to showcase this sort of information.

9. Presentation by Francis Cook

Francis Cook gave an interesting retrospective view of his experiences over many years as editor of *The Canadian Field-Naturalist*.

10. Adjournment

Moved by Fenja Brodo, seconded by Gary McNulty that the meeting be adjourned at 9:40 pm.
(Motion Carried)

KEN ALLISON
Recording Secretary

The Ottawa Field-Naturalists' Club Comittee Reports for 2001

Awards Committee

The following awards for the year 2000 were presented at the OFNC's Annual Soirée, which took place April 27, 2001.

HONORARY MEMBERS

Frank Pope: For his extraordinary and continuing service to the club in almost every capacity.

Donald M. Britton: One of Canada's most distinguished botanists, with very significant contributions to our knowledge of the Canadian fern flora.

John (Jack) M. Gillett: For both his numerous contributions to Canadian botany as well as his many years of service to the OFNC, most recently in his series of articles on the flora of the Ottawa region published in Trail & Landscape (T&L).

Joyce and Allan Reddoch: For their years of service to the OFNC as council members, editor of T&L, articles in T&L, work on conservation matters, and for their contributions to our knowledge of the orchids of the Ottawa region.

MEMBER OF THE YEAR

Sandra Garland: For her work in producing a Club webpage outstanding for its design, ease of use and accuracy, and conducting maintenance on the site to keep it both fresh and timely.

GEORGE MCGEE SERVICE AWARD

Philip Martin: For his many years of service to the Excursions and Lectures Committee both as Chairperson and especially as field trip leader; also his activity in conservation matters, most recently regarding the Leitrim wetlands.

ANNE HANES NATURAL HISTORY AWARD

Robert E. Lee: Principally for his studies of frog populations and his excellent article on the subject in Trail &Landscape, but also for his on-going observations on the natural history of the district.

CONSERVATION AWARD - MEMBER

Albert Dugal: For his on-going and persistent attempts to secure protection for endangered spaces in the Ottawa region, especially the Leitrim Wetlands and South Gloucester Conservation Area, over a number of years.

CONSERVATION AWARD - NON-MEMBER

David Miller, Planner, Region of Ottawa-Carleton: For his significant role in securing protection for a large area of the South March Highlands, his leadership in the Region's Natural Environment Systems Strategy project (NESS), his input into the Regional Official Plan, identifying areas of environmental concern, and many other activities that have helped, and will continue to help preserve the natural environment in the Ottawa District.

I. BRODO

Birds Committee

The Birds Committee participated jointly with the Club des Ornithologues de l'Outaouais to run a successful Christmas Bird Count at the end of 2000. Plans are in place for the 2001 count. We also had a well-attended fall bird count in October 2001. We ran the Peregrine Falcon Watch at the downtown Ottawa nest site, which attracted many volunteers and club members. This year's watch was short lived because the young birds died in collisions with a building. We anticipate running a watch in 2002. The Bird Records Sub-committee met several times during the year to review records of rare birds for the area. Results of their work will appear in an upcoming *Trail & Landscape*. The first year of surveying for the Ontario Breeding Bird Atlas 2nd edition was a great success with almost all our region's squares being covered by an eager team of volunteers. Our seed-a-thon raised around $1000.00 for the Club's bird feeders, which continue to be popular for both birds and

humans. Our bird study group held several sessions during the year which were well-attended. We continue to operate the rare bird alert telephone tree and the Ottawa Bird Status Line, which is a recorded telephone message providing current bird sightings. Two Birds Committee members were featured in a profile of the Ottawa Field-Naturalists' Club in the newspaper of the Peace and Environment Resource Centre.

B. MCBRIDE

Computer Management Committee

The CMC met once in 2001 and identified and performed the following activities:

1. Activity: Since the CMC has been dormant for a few years previous files and information needed to be recovered and filed.

Result: The files were recovered and with the help of Sandra Garland were filed at the Fletcher Wildlife Garden Office.

2. Activity: Recover and update the CMC inventory list.

Result: Alan German recovered and confirmed the inventory list of 14 May 1999.

3. Activity: Upgrade or replace the Club Bookeeper's Computer

Background: Bookeeping is one of the clubs core functions and the existing computer was becoming obsolete and uneconomical to upgrade. The lack of e-mail capability was also a requirement that could not easily be met by the existing computer.

Result: The club recieved a donation of a P100 computer which with the expertise of Roger Camm was outfitted with all necessary equipment to allow it to function. The computer was installed at its final location and is now operational. Thanks to Roger Camm and Alan German.

4. Activity: Membership List Software Upgrade.

Background: The current membership list is in dbase format, which is becoming difficult to maintain.

Result: The database can now be used and modified using a contact management product called Goldmine. Contact management software provides not only easier user interface, but also a path towards such capability as email membership renewals. It was noted that the club membership mailing costs are about $500 annually. A test was designed to show that data records can be exported to Excel and imported into Goldmine. The conversion of all records to Goldmine is ongoing and has taken longer than forecast.

B. ROACH

Conservation Committee

The main activities were in connection with the following:

Richmond Conservation Area (RCA): Robert Marler was nominated to represent OFNC on the advisory committee (RCAMC) which now reports to the City of Ottawa. All nominations and the draft Management Plan are subject to endorsement by City Council. The main issue is whether a permit will be granted for raising the water levels by pumping from the Jock River at times of high flow.

Lac Leamy golf course: Letters were sent to the Ministers of Environment and Canadian Heritage. Our objections apply to the proposed construction of golfing greens on public land in forested areas, at minimal distances from the Lac Leamy wetlands bordering the Ottawa River, and the environmental impact of chemical run-off.

Wetland drainage concerns: In essence, the problem is that existing regulatory controls tend to regard drainage as inherently beneficial, and do not require assessment of damage to significant wetlands that might be caused by drainage of adjoining land. Rosenbaum attended a workshop held by the Ministry of Municipal Affairs and Housing on 4 October 2001 to review the Provincial Policy Statement (PPS) on land use. Main points made: (1) Clause 2.3.4 gives existing agriculture (even when recently-introduced) precedence over any consequences to natural land. (2) The guidelines apply to decision makers (planners and politicians) but not to developers and individuals if actions taken do not require a permit.

Alfred Bog: Negotiations are apparently still ongoing, and no peat extraction is presently taking place within the official boundaries of the bog.

Leitrim Wetlands: Philip Martin attended two meetings of the newly formed Leitrim Wetlands Advisory Committee, set up by South Nation Conservation Authority, and including representation from developers. We are unwilling to endorse any management plan until the future of the entire area of the present wetland has been resolved. Decisions by federal departments (Fisheries and Environment) are delayed, perhaps due to new Transport Canada Risk Assessment investigations on the toxic dump, suggesting increased concern over possible liability if a subdivision is built.

S. ROSENBAUM

Education and Publicity Committee

The committee organized presentations for the national wildlife festival, earth day, environment week, the OC elementary teachers PE Day and Leamy Lake appreciation day. Eight nature walks were conducted and two slide presentations prepared for various groups, including the Trinidad and Tobago Field Naturalist Club, where Tom Bearss, the acting Canadian High Commissioner, spoke on our behalf.

Members of the committee served as judges at the OC Regional science fair. Media relations students at Carleton University were assisted with a class project. Over $500 was raised through sales of club merchandise at outside events and club meetings. Publicity was provided to support club activities and volunteer recognition.

P. PETERKIN

Excursions and Lectures Committee

Excursions and lectures organised monthly evening presentations and field trips throughout the year. The two most significant events were the resignation of Ellaine Dickson (due to ill health) from the Committee after 33 years of service, and the cancellation of the bi-annual trip to Pt. Pelee. This was due to our local Leamington contact booking the wrong dates. The committee is now working on a plan that is 3–6 months ahead of schedule.

R. JOHN

Executive Committee

The Executive Committee met once in 2001 to discuss how the OFNC should handle the request from the Canadian Nature Federation for help in organizing its 2002 annual general meeting – specifically, that OFNC would propose a roster of speakers and trip leaders to the CNF. Executive Committee decided to refer the matter to the Excursions and Lectures Committee, who will set up an 'ad hoc' committee to help the CNF as per their request.

E. ZURBRIGG

Finance Committee

1. The Committee met on three occasions.

In December 2000 the Committee examined the preliminary (pre-audit) Financial Statement for 1999/2000. The audited Statement was approved at the Club's January 2001 Annual Business Meeting. The Statement showed a significant loss on OFNC account offset by a substantial surplus on CFN account. At a meeting in April the Committee reviewed the half-yearly financial performance of the Club. In August, the Committee prepared a draft budget for 2001-2002. The draft, which proposed a balance of revenue and expenditure for both the CFN and OFNC accounts, was presented to Council in September and adopted at its October Meeting. The Committee recommended no change in the membership fee structure.

A. HALLIDAY

Fletcher Wildlife Garden Committee

The level of activity at the Fletcher Wildlife Garden remained steady in 2001, compared with the previous year. The Management Committee met monthly, and volunteers put in about 2000 hours of work. Members of the Friday morning Backyard Garden crew again gave unstintingly of their time every week from April to November to improve this showpiece of the garden. Weekend work days helped with general maintenance and the annual spring plant sale and exchange raised funds for garden operations.

Our summer student proved to be capable, enthusiastic and hard-working. Much of her time was spent on invasive plant control, but she also helped build a fence, repainted our sign, carried out Internet searches and helped visitors, including a number of tourists who discovered the FWG after reading a write-up in Ottawa Magazine. The Interpretation Centre was open for several hours on weekdays and was staffed on Sunday afternoons by volunteers. Exhibits inside were revised and enlarged and the floor was repainted. The centre was broken into twice, but with no significant loss of contents. A telephone (613-234-6767) was installed in the spring to provide a message system, emergency communication, and Internet access.

Carleton University has continued with the swallowwort project, doing basic biology and testing non-chemical control methods on test plots. Notices to explain the project were erected, although the material was vandalized repeatedly. Wildlife gardening publications and newsletters were produced and disseminated to the public; these were funded by a grant obtained from the Canada Trust Friends of the Environment Program. The FWG continued to be a central location for OFNC activities, Council and at least six committees and subcommittees meet regularly in the Interpretation Centre, as does the Ottawa Stewardship Council. Although the FWG's financial position is quite good, all income in 2001 came from the OFNC allocation, the Taverner Cup, and donations from individuals. The committee would like to apply for funding for better signage, but is constrained by the lack of a formal agreement with Agriculture and Agri-Food Canada.

Although the FWG has a roster of enthusiastic volunteers, the management committee continues to shrink, making it difficult to organize and supervise work parties.

D. HOBDEN

Macoun Field Club Committee

The committee met five times to plan the weekly meetings for the children and young people of the Macoun Field Club through the course of the school year. Committee members arranged speakers and workshops for the Friday afternoon and Saturday morning meetings, and they led 16 field trips and 3 camping trips. Membership was a concern only in the two youngest age-groups, which had to be combined.

There were 22 Juniors/Intermediates (8-13 years of age) and 20 Seniors (high school age) involved in the Macoun Club this year.

R. LEE

Membership Committee

The distribution of memberships for 2001 is shown in the table (below), with the comparable numbers for 2000 in brackets. These statistics do not include three complimentary memberships awarded to winners of the 2001 Science Fair competition nor the 23 affiliate organizations which receive copies of the Club's publications.

Distribution of Memberships in The Ottawa Field-Naturalists' Club

	CANADIAN		FOREIGN		
Type	Local	Other	USA	Other	Total
Family	345 (350)	31 (23)	3 (2)	2 (1)	381 (376)
Individual	366 (340)	121 (122)	22 (25)	4 (4)	513 (491)
Honorary	17 (15)	8 (8)	0 (0)	0 (0)	25 (23)
Life	21 (22)	22 (21)	5 (5)	1 (1)	49 (49)
Sustaining	8 (8)	2 (1)	0 (0)	0 (0)	10 (9)
Total	757 (735)	184 (175)	30 (32)	7 (6)	978 (948)

This year the Club awarded Honorary Memberships to five persons. Three prominent and long-time members of the Club passed away this year. Dr. D. E. McAllister was an Honorary and member of the Club since 1958. Patricia (Mickey) Narraway was a member of Council for many years and a member of the Club since 1967. Dr. W. E. Ricker had been a member of the Club since 1930, perhaps the longest tenure in the history of the Club.

D. SMYTHE

Publications Committee

The Publications Committee met twice in 2001.

Three issues of *The Canadian Field-Naturalist* were published in 2001; Volume 114, #4, and Volume 115, #1, 2. These three issues contained in 598 pages: 46 articles; 23 notes; 4 COSEWIC articles; 28 book reviews; 147 new titles; 3 commemorative tributes; 12 pages of News and Comment; and a 34-page index. An Associate Editor for mammalogy, W. Ballard, retired and was sent a certificate of appreciation for his seven years of service. There were no other changes in the panel of Associate Editors. Five articles received support from the Manning Memorial Fund, for a total of eight to date.

Volume 35 of *Trail & Landscape* was published in four issues containing 228 pages. This was the largest volume in some years because it contained two lengthy articles: Consaul, Dugal, and Boles on the Leitrim wetlands and Coad on a key to the fishes of the National Capital Region; and a five-year index. Fenja Brodo retired as Editor and Sandra Gushue as Production Manager with the publication of Issue 1, both after ten years of service. They have remained on the staff as Associate Editor and Production Assistant, respectively. With Issue 2, Karen McLachlan-Hamilton took over as Editor. The Club owes a huge debt of gratitude to all of these people.

R. BEDFORD

Auditor's Report

To The Members of THE OTTAWA FIELD-NATURALISTS' CLUB

I have audited the balance sheet of THE OTTAWA FIELD-NATURALISTS' CLUB as at September 30, 2001, the statement of changes in net assets, and the statements of operations. These financial statements are the responsibility of the organization's manage-ment. My responsibility is to express an opinion on these statements based on my audit.

Except as explained in the following paragraph, I conducted my audit in accordance with generally accepted auditing standards. Those standards require that I plan and perform an audit to obtain reasonable assurance whether the financial statements are free of material misstatement. An audit includes examining evidence supporting the amounts and disclosures in the financial statements. An audit also includes assessing the accounting principles used and significant estimates made by management, as well as evaluating the overall financial statement presentation.

In common with many non-profit organizations, The Ottawa Field-Naturalists' Club derives some of its revenue from memberships, donations, and fund raising activities. These revenues are not readily susceptible to complete audit verification, and accordingly, my verification was limited to accounting for the amounts reflected in the records of the organization.

In my opinion, except for the effect of the adjustments, if any, which I might have determined to be necessary had I been able to satisfy myself concerning the completeness of the revenues referred to in the preceding paragraph, these financial statements present fairly, in all material respects, the financial position of the OFNC as at September 30, 2001, and the results of its operations and changes in net assets for the year then ended in accordance with generally accepted accounting principles.

JANET M. GEHR
Chartered Accountant

North Gower, Ontario
December 18, 2001

The Ottawa Field-Naturalists' Club
Balance Sheet
September 30, 2001

	2001	2000
ASSETS		
CURRENT		
Cash (Note1)	$ 50,760	$ 9,519
Investment certificates (Note 1)	110,219	106,939
Marketable securities (Note 2)	194,234	185,765
Accounts receivable	5,386	19,689
Prepaid expenses	1,000	1,000
	361,599	322,912
CAPITAL ASSETS (Note 3)	–	–
Land — Alfred Bog	3,348	3,348
	$ 364,947	$ 326,260
LIABILITIES AND FUND BALANCES		
CURRENT		
Accounts payable and accrued liabilities	$ 2,000	$ 2,000
Deferred revenue	13,788	13,532
	15,788	15,532
Life memberships	11,721	11,249
NET ASSETS		
Unrestricted	99,427	66,721
Club reserve	100,000	100,000
Manning principal	100,000	100,000
Manning interest – OFNC	2,186	1,203
– CFN	8,225	4,813
Seedathon	1,569	1,308
Anne Hanes Memorial	870	870
de Kiriline-Lawrence	24,553	22,941
Macoun Baillie Birdathon	(7)	1,039
Alfred Bog	615	584
	337,438	299,479
	$ 364,947	326,260

The Ottawa Field-Naturalists' Club
Statement of Operations
For the Year Ended September 30, 2001

	2001	2000
REVENUE		
Memberships	$ 15,675	$ 15,355
Trail & Landscape	266	224
Interest	2,203	1,433
GST rebate	–	915
Other	984	680
	19,128	18,607
OPERATING EXPENSES		
Affiliation fees	455	1,309
Computer	534	444
Membership	1,365	1,732
Office assistant	1,000	1,000
Telephone	1,593	1,206
Insurance	688	655
Audit	1,000	1,000
GST	1,505	1,494
Operations	782	2,037
	8,922	10,877
CLUB ACTIVITY EXPENSES		
Awards	280	215
Birds	466	875
Education and Publicity	182	387
Excursions and Lectures	(311)	(98)
Macoun Field Club	955	1,151
Soiree	65	429
Trail & Landscape	8,794	8,256
Fletcher Wildlife Garden	(2,281)	2,132
Other	265	(66)
	8,415	13,281
	17,337	24,158
EXCESS REVENUE OVER EXPENSES	$ 1,791	$ (5,550)

The Ottawa Field-Naturalists' Club
Statement of Operations —
The Canadian Field-Naturalist
For the Year Ended September 30, 2001

	2001	2000
REVENUE		
Memberships	$10,447	$ 10,253
Subscriptions	28,869	26,509
Reprints	10,654	7,033
Publication charges	30,212	39,888
Interest and exchange	17,386	8,519
GST rebate	–	4,590
Other	330	706
	97,898	97,498
EXPENSES		
Publishing	35,108	58,461
Reprints	9,430	6,135
Circulation	7,942	6,070
Editing	3,628	3,258
Office Assistant	5,000	5,000
Honoraria	6,000	6,000
GST	3,867	6,045
Other	1,028	2,020
	72,003	92,989
EXCESS REVENUE OVER EXPENSES	$25,895	$4,509

The Ottawa Field-Naturalists' Club Statement of Changes In Net Assets
For the Year Ended September 30, 2001 (Note 5)

Net Assets	Beginning Balance	Excess Revenue CFN	Excess Revenue OFN	Other Revenue	Expenses	Ending Balance
Unrestricted	$ 66,721	$ 25,895	$ 1,791	$ 5,020 (a)	$ -	$ 99,427
Club Reserve	100,000	-	-	-	-	100,000
Manning – Principal	100,000	-	-	-	-	100,000
Manning – OFNC	1,203	-	-	1,203 (b)	220 (d)	2,186
Manning – CFN	4,813	-	-	4,812 (b)	1,400 (e)	8,225
Seedathon	1,308	-	-	794 (c)	533	1,569
Anne Hanes Memorial	870	-	-	-	-	870
de Kirilin-Lawrence	22,941	-	-	1,612 (c)	-	24,553
Macoun Baillie Birdathon	1,039	-	-	275 (c)	1,321 (f)	(7)
Alfred Bog	584	-	-	31 (c)	-	615
	$ 299,479	$ 25,895	$ 1,791	$ 13,747	$ 3,474	$ 337,438

The Ottawa Field-Naturalists' Club
Summary of Significant Accounting Policies

September 30, 2001

1. Nature of Business

The organization is non-profit and incorporated under the laws of Ontario (1884). The organization promotes the appreciation, preservation, and conservation of Canada's natural heritage. It encourages investigation and publishes the results of the research in all fields of natural history and diffuses information on these fields as widely as possible. It also supports and cooperates with other organizations engaging in preserving, maintaining or restoring environments of high quality for living things.

2. Financial Instruments

The organization's financial instruments consist of cash, accounts receivable, marketable securities, and accounts payable. Unless otherwise noted, it is the management's opinion that the organization is not exposed to significant interest, currency, or credit risks arising from these financial instruments. The fair value of these instruments approximate their carrying values.

3. Capital Assets

Capital assets acquired after 1989 are expenses. Capital assets acquired prior to 1990 were recorded as assets at cost and amortized on a straight-line basis. These assets have been fully amortized.

4. Statement of Changes in Financial Position

A statement of changes in financial position has not been provided as it would not provide additional meaningful information.

5. Foreign Currency

Transactions during the year in U.S. dollars have been converted in the accounts to Canadian dollars at the exchange rate effective at the date of the transaction. All monetary assets in U.S. dollars at year end have been converted to Canadian dollars at the rate effective on Sept. 30, 2001. Gains or losses resulting therefrom are included in revenue or expenses.

The Ottawa Field-Naturalists' Club Notes to the Financial Statements
September 30, 2001

1. CASH

	2001	2000
Chequing	$ 3,358	$ 3,008
Savings	36,984	3,602
Nesbitt Burns	4,265	13
Fletcher Wildlife Garden	6,153	2,896
	$ 50,760	$ 9,519

Investment Certificates:	Maturity Value	Maturity Date	Yield	Book Value
	$ 19,981	11/29/01	4.45%	$ 19,838
	27,286	12/11/01	4.20%	27,066
	21,428	12/28/01	4.00%	21,224
	42,874	04/30/02	3.25%	42,091
				$ 110,219

2. MARKETABLE SECURITIES

	Maturity Value	Maturity Date	Yield	Book Value
Ontario Hydro Coupon	$ 47,654	06/24/02	6.0%	$ 45,767
Government of Canada Coupon	30,167	12/01/09	5.605%	19,338
Province of Manitoba Coupon	29,847	11/15/04	5.119%	25,569
Province of New Brunswick Bond	20,000	06/15/10	6.231%	21,050
Province of Newfoundland Bond	20,000	10/07/08	6.263%	20,538
Ontario Savings Bonds	40,000	06/21/05	6.45%	41,260
Ontario Savings Bonds	20,000	06/21/03	6.5%	20,712
				$ 194,234

3. CAPITAL ASSETS
Equipment at cost of $16,748 is fully amortized.

4. FLETCHER WILDLIFE GARDEN

	2001	2000
REVENUE		
Federal government	$ 3,055	$ -
Other	5,262	2,982
	8,317	2,982
EXPENSES		
Program	3,220	-
Backyard	311	797
Habitats	51	1,086
Other	2,454	3,230
	6,036	5,113
	$ 2,281	$ (2,131)

5. STATEMENT OF CHANGES IN NET ASSETS
(a) Unrestricted donation;
(b) Interest earned on Manning principal;
(c) Restricted donation;
(d) Peregrine watch;
(e) CFN articles: Vol 113(3), Birds and Mammals in Thelon, Vol 113(4) Quillworts in Yukon, Frogs at Churchill;
(f) Video camera.

Miscellaneous: Life in the Treetops: Adventures of a Woman in Field Biology — Victorian Sensations: The Extraordinary Publication, Reception, and Secret Authorship of the *Vestiges of the Natural History of Creation* — Northern Wild, Best Contemporary Canadian Nature Writing — Cheltenham in Antarctica: The Life of Edward Wilson 508

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The CANADIAN FIELD-NATURALIST

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The Ottawa Field-Naturalists' Club

FOUNDED IN 1879

Patrons

Her Excellency The Right Honourable Adrienne Clarkson, C.C., C.M.M., C.D.
Governor General of Canada
His Excellency John Ralston Saul, C.C.

The objectives of this Club shall be to promote the appreciation, preservation and conservation of Canada's natural heritage; to encourage investigation and publish the results of research in all fields of natural history and to diffuse information on these fields as widely as possible; to support and cooperate with organizations engaged in preserving, maintaining or restoring environments of high quality for living things.

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Kathy Conlan	Beverly McBride	Dorothy Whyte

To communicate with the Club, address postal correspondence to: The Ottawa Field-Naturalists' Club, Box P.O. Box 35069, Westgate P.O. Ottawa, Canada K1Z 1A2, or e-mail: ofnc@achilles.net.
For information on Club activities telephone (613) 722-3050 or check http//www.achilles.net/ofnc/index.htm

The Canadian Field-Naturalist

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All manuscripts intended for publication should be addressed to the Editor and sent by postal mail. Exception: book reviews should go directly to Book Review Editor.

Subscriptions and Membership
Subscription rates for individuals are $28 per calendar year. Libraries and other institutions may subscribe at the rate of $45 per year (volume). The Ottawa Field-Naturalists' Club annual membership fee of $28 (individual) $30 (family) $50 (sustaining) and $500 (life) includes a subscription to *The Canadian Field-Naturalist.* All foreign subscribers and members (including USA) must add an additional $5.00 to cover postage. The club regional journal, *Trail & Landscape*, covers the Ottawa District and Local Club events. It is mailed to Ottawa area members, and available to those outside Ottawa on request. It is available to Libraries at $28 per year. Subscriptions, applications for membership, notices of changes of address, and undeliverable copies should be mailed to: The Ottawa Field-Naturalists' Club, P.O. Box 35069, Westgate P.O. Ottawa, Canada K1Z 1A2. Canada Post Publications Mail Agreement number 40012317. Return Postage Guaranteed. Date of this issue: October–December 2002. (May 2003).

Cover: Brittle Prickly-pear Cactus, *Opuntia fragilis*, at Mellon Creek, Kaladar, Ontario, (*SJD 5014* DAO) photographed 27 June 1999 by Stephen J. Darbyshire. *See* Staniforth, Cody, and Frego pages 4547–550.

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Rapid Estimation of Plant Biomass Used as Forage or Cover by White-tailed Deer, *Odocoileus virginianus*, and Snowshoe Hare, *Lepus americanus*, in Mixed and Coniferous Forests of Southeastern Québec

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Estimation of vegetation biomass in forest ecosystems is time-consuming because of inherent high variability. We developed 10 linear regression models to predict standing dry biomass of most plant taxa potentially used as forage or cover by White-tailed Deer and Snowshoe Hare in forests of southeastern Québec. Vertical interception and lateral coverage, which served as explanatory variables in regressions, were measured along 2-m transects before clipping, drying and weighing vegetation. Plant species with similar morphology and size were pooled. Although we collected vegetation samples from two areas 400 km apart, we could combine data for regressions except for low herbs (< 30 cm). Models covered a wide range of biomass and fitted the data reasonably well when ln-transformed, with R^2 values varying between 0.61 and 0.85. Cross-validation confirmed model robustness.

Key Words: biomass, boreal, cover, forage, forest, linear regression, method, mixed, Québec, technique

L'estimation de la biomasse végétale dans les écosystèmes forestiers demeure laborieuse à cause de son inhérente grande variabilité. Nous avons développé 10 modèles de régression qui prédisent la biomasse de la plupart des taxa végétaux potentiellement utilisés comme nourriture ou couvert par le cerf de Virginie et le lièvre d'Amérique dans les forêts du sud-est québécois. L'interception verticale et le recouvrement latéral des espèces végétales, qui ont servi de variables explicatives dans les modèles, furent mesurés au-dessus de parcelles linéaires de 2 m, avant qu'on coupe, sèche et pèse les végétaux. Les espèces végétales avec un port et une taille semblables ont été regroupées. Bien que les échantillons fussent recueillis dans deux régions séparées de 400 km, il fut possible de les regrouper sauf pour les herbacées basses (< 30 cm). Les modèles ont couvert une gamme étendue de biomasse et se sont ajustés relativement bien aux données après une transformation logarithmique, avec des R^2 compris entre 0,61 et 0,85. Une validation croisée a confirmé la robustesse des modèles.

Mots clefs: biomasse, boréale, faune, forêt, mélangée, méthode, Québec, régression linéaire, technique.

During concurrent studies on the summer habitat of White-tailed Deer (*Odocoileus virginianus*; Rouleau et al. 2002) and the space used by Snowshoe Hare (*Lepus americanus*) in summer and in winter (Beaudoin 2001), we were confronted by the need to quantify forage and cover availability. We wanted to estimate plant biomass because direct measurements of vegetation represent a prerequisite for improving our understanding of wildlife-habitat relationships (Morrison et al. 1998: 151). The large spatial variability of plant biomass (e.g., Crête and Jordan 1982; Crête 1989 ; Crête and Courtois 1997) requires large sample sizes, which are time-consuming.

As shoulder height of adult White-tailed Deer averages 92 cm (Banfield 1977), 1.5-m high vegetation suffices to completely hide this species. When foraging, White-tailed Deer zigzag slowly and rarely browse plants above 1.5 m from the ground. Snowshoe Hare can feed on twigs up to 45 cm above snow surface when standing on their hind feet (Banfield 1977). When resting or standing on their feet, hare require dense vegetation up to around 30 cm to be hidden from the view of terrestrial predators. Hare are well adapted for locomotion in the snow (Murray and Boutin 1991), and generally feed and move on the top of the snow pack. Snow depth

varies between 50 and 100 cm during winter in southeastern Québec (e.g., Dumont et al. 2000). When stratifying the vegetation likely to serve as food or cover for White-tailed Deer and hare, we then used three practical thresholds for height classes: 30 cm, 50 cm, and 150 cm.

Methods exist to estimate vegetation volume or biomass quickly with auxiliary variables which can be measured rapidly (e.g., Bonham 1989; Crête et al. 1990b), but none were adapted to our needs. In this study, we wanted to determine whether we could predict, with simple and rapid measurements, plant biomass growing in the 0-1.5 m stratum for mixed and coniferous forests of varying ages in south-eastern Québec. As we tallied 214 taxa of herbs and woody species in the deer range in Québec (Boucher 2003), we had to pool species based on their growth form to obtain adequate sample sizes for each regression model.

Study Area and Field Methods

We studied plant biomass in the Bas-Saint-Laurent (≈48° 00' N; ≈69° 00' W) and Montérégie (≈46° 00' N; ≈73° 00' W) regions of Québec during the growing seasons of 1998 and 1999. The Bas-Saint-Laurent region occupies a transition zone between the northern hardwood forest and the boreal forest; Sugar Maple (*Acer saccharum*) and Yellow Birch (*Betula alleghaniensis*) often grow on hilltops and well-drained hillsides, whereas Balsam Fir (*Abies balsamea*), White and Black spruce (*Picea glauca, P. mariana*) frequently dominate with Trembling Aspen (*Populus tremoloides*) and White Birch (*Betula papyrifera*) elsewhere (Rowe 1972). Most forest stands have been affected by logging, insect epidemics, or fire during the last century. The milder climate in Montérégie favours the growth of a greater variety of tree species, including Sugar Maple, Yellow Birch, White Ash (*Fraxinus americana*), American Linden (*Tilia americana*), Ironwood (*Ostrya virginiana*), White Pine (*Pinus strobus*) and Hemlock (*Tsuga canadensis*; Rowe 1972). Commercial logging appears to have been less important in Montérégie than in Bas-Saint-Laurent, likely due to a fragmented pattern of land ownership, but human activity has affected most forest stands. Aerial surveys carried out in early winter revealed that White-tailed Deer density averaged 1 individual km^{-2} in Bas-Saint-Laurent (1999) and 12 individuals km^{-2} in Montérégie (1997). Deer browsing likely reduced plant biomass in the latter region, while browsing impact remained negligible in the former (Rouleau et al. 2002).

We collected vegetation samples during the growing season between 3 June 1998 and 31 August 1999. Green-up begins in early May in Montérégie and two or three weeks later in Bas-Saint-Laurent (Lesage et al. 2000). Samples came from sites used by radio-collared White-tailed Deer (n = 109) and Snowshoe Hare (n = 23), or from 17 grids used to estimate small mammal and hare density (n = 66). Seven observers participated in the study.

We used a line-intercept technique to estimate vegetation biomass (e.g., Crête et al. 1990a). Sampling plots were 2 m long and the location of their starting point coincided with a previous telemetry location of White-tailed Deer or hare, or a predetermined point on permanent grids used for estimating hare or small mammal density. Transect orientation was selected randomly. Observers located sampling plots with a hip chain and a compass. We made a length and height assessment of plant coverage by species (genus or family, depending on ease of taxonomic identification). To facilitate data collection, plants up to 150 cm tall were recorded in two sequences. First, we recorded lycopods, trees and shrubs < 50 cm tall and all herbs. Secondly, we recorded all the foliage from 0-150 cm on trees and shrubs that exceeded 50 cm in height. We omitted lichens and mosses due to their rarity in both regions.

We placed a 1-1.5 cm wide measuring tape on the ground surface for recording measurements, using the metric side as the sampling line. The observer stood perpendicular to the sampling line and recorded the position of the beginning and end of each vertical interception of the line by species, genus, or family to the nearest cm. The difference between the end and beginning of each interception yielded the

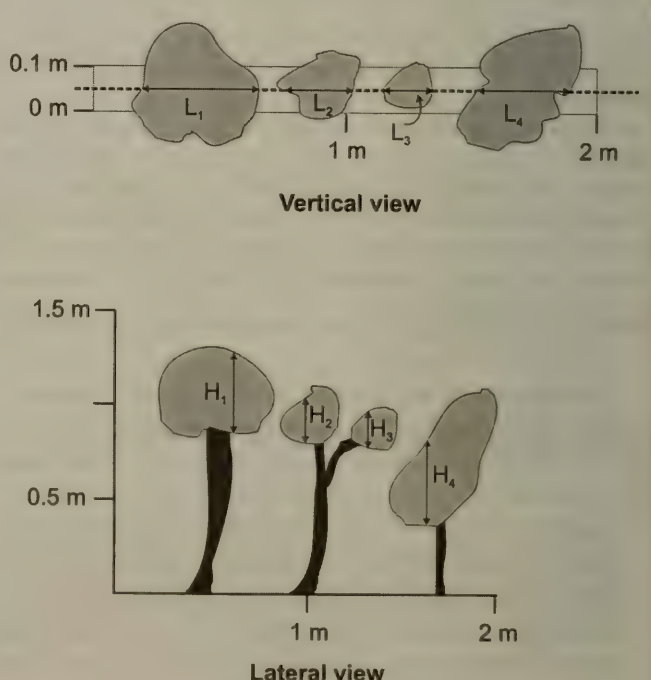

FIGURE 1. Schematic representation of vertical interception and lateral coverage measurements taken on three shrubs with foliage intercepting the sampling line (dotted line on vertical view) and surface area (vertical view) from which foliage was clipped, dried and weighed (0.1 m × 2 m). See text for details.

length (L; Figure 1), with a minimum of 1 cm (i.e., if L < 1, then L = 1). The observer then estimated, from a lateral view, the average height (H) of the green plant material associated with each interception within a 5-cm strip on each side of the sampling line (see below). H included leaves and stems of herbs but only foliage of woody species (Figure 1). We did not distinguish individual plants for herbaceous or woody species, so a single plant could provide several measurements if line interceptions originating from the same stem were separated by an unoccupied space (Figure 1).

We then collected the green vegetation present within 5 cm of both sides of the sampling line (0.2 m^2) and from the ground to a height of 150 cm (0.3 m^3). We used wooden poles and elastic cords to delimit the sampling volume. We harvested herbs with pruning shears from the ground when originating in the sampling surface. We collected only the leaves of deciduous woody species whereas we collected needle-bearing twigs plus needles for conifers. Samples were sorted by species and placed in plastic or paper bags for transportation, except for woody deciduous species > 50 cm, whose leaves were pooled. Vegetation samples were dried in an oven at 40-60°C until weight stabilisation and weighed with a precision of ± 0.01 g.

Statistical Analysis

To obtain adequate sample sizes, we pooled data into 10 categories based on morphological and size similarities (Table 1); we used species description by Marie-Victorin (1995) to partition species into categories. We ln-transformed all biomass data because distributions were log-normal. The validity of this transformation was tested by fitting a generalised gamma model to the data and testing at $\alpha = 0.05$ for the shape of the parameter to be equal to 0 with the Lagrande multiplier chi-square statistic (Proc Lifereg, SAS 1989). Furthermore, this trans-

TABLE 1. Species composition of 10 plant categories with morphological similarities and likely to serve as forage and cover for wildlife in mixed and coniferous forests of northeast North America.

Plant categories	Species composition
Herbs < 30 cm (Bas Saint-Laurent)	*Clintonia borealis, Coptis groenlandica, Chiogenes hispidula, Cornus canadensis, Epigaea repens, Fragaria* sp., *Hieracium* sp., *Linnaea borealis, Maianthemum canadense, Oxalis montana, Pyrola* sp., *Taraxacum* sp., *Trientalis borealis, Viola* sp.
Herbs < 30 cm (Montérégie)	*Circea lutetiana, Clintonia borealis, Coptis groenlandica, Cornus canadensis, Dalibarda repens, Fragaria* sp., *Maianthemum canadense, Mitchella repens, Mitella diphylla, M. nuda, Oxalis montana, O. stricta, Taraxacum* sp., *Tiarella cordiafolia, Trientalis borealis, Viola* sp.
Herbs ≥ 30 cm	*Anaphalis margaritacea, Aralia nudicaulis, A. hispida, Aster* sp., *Centaurea nigra, Epilobium angustifolium, E. glandulosum, Eupatorium rugosum, Impatiens capensis, I.* sp., *Lycopus americanus, Lysimachia nummularia, L. terrestris, Mimulus ringens, Ranunculus acris, Senecio* sp. *Solidago* sp., *Thalictrum* sp.
Ferns	*Athyrium filix-femina, Dennstaedtia punctilobula, Dryopteris* sp., *Matteuccia struthiopteris, Onoclea sensibilis, Osmunda cinnamomea, O. claytoniana, O. regalis, Pteridium aquilinum*
Graminoids	Cultivated and native Graminae, Cyperacae
Deciduous seedlings (< 50 cm)	*Acer* sp., *Alnus rugosa, Amelanchier* sp., *Betula papyrifera, B. populifolia, B.* sp., *Corylus cornuta, Fraxinus americana, Ostrya virginiana, Populus tremuloides, Prunus serotina, Tilia americana, Ulmus americana*
Small deciduous shrubs (< 50 cm)	*Cornus stolonifera*[a], *Diervilla lonicera, Kalmia angustifolia, Lonicera canadensis*[a], *Myrica gale*[a], *Nemopanthus mucronatus*[a], *Ribes* sp., *Rhododendron canadense, Rhus radicans, Rubus* sp.[a], *Spiraea latifolia*[a], *Vaccinium* sp.
Large shrubs and trees (deciduous; > 50 cm)	*Acer pensylvanicum, A. rubrum, A. saccharum, A. spicatum, Alnus rugosa, Amelanchier* sp., *Betula populifolia, Corylus cornuta, Fraxinus americana, Ledum groenlandicum, Populus tremuloides, Prunus pensylvanica, P. serotina, Rhamnus alnifolius, Viburnum alnifolium*
Balsam Fir	*Abies balsamea*
Spruces	*Picea glauca, P. mariana, P. rubens*
White Cedar	*Thuja occidentalis*

[a]Some samples were included in the categorie "Large shrubs and trees" when >50 cm

formation generally minimised the error sum of squares among all transformations in the Box-Cox family. We used two independent variables to predict plant biomass per sampling plot: L and H. L represented the sum of the interception lengths per plot for a plant species, genus, or family (i.e., $\sum L_n$: Figure 1), while H was the mean weighted height (i.e., $\sum H_n \cdot L_n/L$: Figure 1). We considered all combinations of the two independent variables (non-transformed, ln(X), X^2, $X^{1/2}$, etc.), including polynomial relationships, to select the regression models that best fitted the biomass data. We chose as the final model the most parsimonious one, i.e., the model with the highest adjusted R^2 which included only significant explanatory variables ($P < 0.05$), ensuring that residuals were normally distributed (Shapiro-Wilk test), homogenous and without patterns (visual examination of the plot). In addition, we used the Dffits, Hatdiag and CovRatio statistics (Proc Reg, SAS 1989) to detect influential data points. We introduced indicator variables (Neter et al. 1985) and interaction terms into the regression models to test whether we could pool observations from the two study regions. We used leave-one-out cross-validation (Stone 1974) to check the robustness of regression models. We systematically excluded one data point at a time and predicted its value with the regression model adjusted with the remaining data set (SAS 1989). We then computed the coefficient of determination between observed and predicted values to ascertain how they matched.

Results

Apart from lycopods, for which we could not fit a model due to the small sample size (n = 7), we found highly significant ($P < 0.0001$) regression models predicting dry plant biomass for all plant categories (Table 2). We collected samples in both regions for all plant categories except coniferous trees (fir, spruces and White Cedar: *Thuja occidentalis*). Our statistical analysis revealed that we could pool samples from the two regions, except for low herbs, for which the intercept differed ($P < 0.0001$: Table 2). The regression models explained between 61 and 85% of the variability in biomass for the 10 plant categories. Only total length of vertical interception (L) significantly predicted biomass of low herbs, graminoids, deciduous seedlings and small deciduous shrubs, while both length of vertical interception and height of lateral coverage (H) were significant factors for ferns, tall herbs and large woody plants (Table 2). For Balsam Fir and White Cedar, parameter estimates for the two independent variables (L and H) did not differ ($P > 0.05$) so we used the product (L×H) to predict plant biomass. R^2 computed during cross-validation were generally 2-3% lower than those for models fitted with full data sets.

TABLE 2. Characteristics of regression models developed to predict green biomass for 10 plant categories for the 0-150 cm height stratum in mixed and coniferous forests in southeastern Québec. Models predict dry mass in g per 0.2 m^2 or 0.3 m^3 depending on whether expressed as surface area or volume. The value, MSE/2, must be added to the predicted ln biomass before transforming back to the normal scale to prevent bias (Ung and Végiard 1988).

Plant group	Regression model[a] ln (biomass) =	Adjusted R^2 (Cross-validation R^2)	Mean Squared Error (MSE)	N	Range in biomass (g)[b]
Herbs < 30 cm (Bas-Saint-Laurent)	- 2.7647 + 1.0173 ln (L)	0.72 (0.71)	0.6480	84	0.01-9.99
Herbs < 30 cm (Montérégie)	- 4.0254 + 1.0173 ln (L)	0.72 (0.71)	0.6480	58	0.01-1.09
Herbs ≥ 30 cm	- 2.7485 + 0.7296 ln (L) + 0.3861 ln(H)	0.66 (0.63)	0.8451	81	0.01-57.93
Ferns	- 3.9042 + 0.9485 ln (L) + 0.4110 ln(H)	0.75 (0.74)	0.7147	119	0.01-39.44
Graminoids	- 3.8217 + 1.3297 ln (L)	0.79 (0.77)	0.7906	38	0.01-30.75
Deciduous seedlings (< 50 cm)	- 3.3175 + 0.9911 ln (L)	0.61 (0.59)	0.9346	55	0.01-7.95
Small deciduous shrubs (< 50 cm)	- 2.9772 + 0.9643 ln (L)	0.65 (0.63)	0.6631	74	0.02-23.46
Large shrubs and trees (deciduous; > 50cm)	- 3.5029 + 0.8960 ln (L) + 0.4218 ln (H)	0.82 (0.81)	0.4159	49	0.05-44.64
Balsam Fir	- 3.0136 + 0.7503 ln (L(H)	0.79 (0.77)	0.4798	46	0.33-141.00
Spruces	- 2.2202 + 1.0608 ln (L) + 0.2533 ln (H)	0.81 (0.78)	0.3456	32	1.13-137.67
White Cedar	- 3.7381 + 0.8008 ln (L×H)	0.85 (0.82)	0.2894	25	0.66-82.48

[a] L = total length (cm); H = mean weighted height (cm);
[b] Minimum and maximum values that were used to fit the models

Discussion

Modelling generally necessitates simplification of study systems and our work was no exception. We hypothesized that we could describe most variation in dry plant biomass from rapid measurements taken in two dimensions: vertical interception for length and lateral coverage for height (L and H, respectively). In addition, we assumed that biomass density and spatial arrangement remained relatively similar for plant taxa pooled within categories (Table 1). We conclude that such assumptions were valid, given that most adjusted R^2 values exceeded 0.70. Cross-validation confirmed model robustness. In general, biomass of low vegetation could be estimated using only vertical interception whereas biomass prediction of taller plants necessitated both vertical and lateral measurements. This may partly depend on the precision of our measurements (1 cm), which were proportionally more imprecise for small plants. Height also served to predict fern biomass probably because the species sampled (Table 1) exhibit large size variation. The more complex models for tall plants could also depend on more complex architecture than that of low vegetation. In general, biomass of conifers exceeded that of woody deciduous species by a factor of 2 to 10 for comparable L and H measurements. This result is likely due to the inclusion of twigs bearing needles for conifers in addition to the higher specific leaf area in coniferous than deciduous species (Lei and Lechowicz 1990; Sprugel et al. 1996; Reich et al. 1998).

We only found one significant ($P < 0.0001$) regional difference when adjusting our models to predict plant biomass, and that was for herbaceous species smaller than 30 cm in height. The two regional models differed only in intercept, and produced biomass predictions differing by a factor of 3.53. We believe that such a difference arose from different species composition (Table 1) and dominance, and from the high White-tailed Deer density in Montérégie, which has likely reduced plant size (e.g., Balgooyen and Waller 1995).

The models that we computed are relatively robust because we used data collected by different crews in two different areas separated by approximately 400 km. Likewise, our models should produce reasonable estimates of biomass for most plant taxa growing in Ontario, Québec and in adjacent parts of southwest New York, Vermont, Maine, and New Brunswick. Further away, researchers or managers could use double sampling (Bonham 1988: 202) to alleviate potential biases. Our model can serve for studies on White-tailed Deer or Snowshoe Hare, but also for other animal taxa which use the 0-1.5-m high stratum in forest ecosystems. Users should consider White-tailed Deer density when predicting biomass of low herbs; we suggest using the model computed in Montérégie if deer density exceeds 10 animals km^{-2}. Although data collection is rapid, the use of our regression models necessitates careful field measurements to produce unbiased estimates. One should always imagine the volume of reference; i.e., 5 cm on each side of the transect line, when estimating lateral coverage. In addition, users must tally only plant specimens with vertical interception; plants present in the sampling volume but not crossing the transect line must be ignored.

We already successfully used our models for detecting habitat preferences in Snowshoe Hare (Beaudoin 2001) and White-tailed Deer (Rouleau et al. 2002.). Given that we pooled plant species to compute our models, they can serve to predict biomass of any species; e.g., of preferred forage species only. We did not measure the time necessary to sample plots, but it took approximately 5 to 20 min to survey a plot, depending on vegetation density. Our method, coupled with plotless tree measurements (e.g., Grosenbaugh 1952) and sapling counts in circular plots, will allow a rapid and complete characterisation of forest stands (e.g., Beaudoin 2001). Our results illustrate that relationships between vegetation coverage and biomass are curvilinear (all biomass data ln-transformed), and thus the use of linear indices of vegetation abundance may preclude finding significant wildlife-habitat relationships.

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Selection, Size, and Use of Home Range of the Appalachian Cottontail, *Sylvilagus obscurus*

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Little is known about the ecology of the Appalachian Cottontail (*Sylvilagus obscurus*) in the northern portion of its range. We studied selection, size and use of home range for eight radio-collared Appalachian cottontails in western Maryland from February to July 1995. Home ranges were large and highly variable. For both sexes combined, median 100% minimum convex polygon (MCP), 95% MCP, and 95% adaptive kernel home ranges measured 5.4, 4.3, and 4.7 ha, respectively. Home ranges had greater amounts of understory cover and lesser slopes (≤25°) than the surrounding landscape. Rabbits used portions of home ranges in close proximity (<2 m) to concealment cover, with canopy closure <95%, and with Blackberry, *Rubus alleganiensis*, as the dominant shrub species; they avoided places >10 m from concealment cover, with low stem density (<20 stems/1-m radius plot), and with 95–100% canopy closure. Dense understory concealment and escape cover seemed to be more important than species of vegetation to Appalachian Cottontails in Maryland. Our results suggest that fragmentation of habitat could limit the distribution of the species. We also demonstrate the importance of analyzing individual variation of life history characteristics in addition to measures of central tendency.

Key Words: Appalachian Cottontail, *Sylvilagus obscurus*, cover, habitat, home range, individual variation, adaptive kernel, minimum convex polygon, radiotelemetry.

The Appalachian Cottontail (*Sylvilagus obscurus*) occurs from northeastern Pennsylvania, south through the Appalachian Mountains to northern Georgia (Chapman et al. 1992). During the past half century, however, the numbers and ranges of this and its more northern sister species, *S. transitionalis* (New England Cottontail), have decreased (Merritt 1987). *Sylvilagus transitionalis* [which some believe is conspecific with *S. obscurus*] is considered nationally "vulnerable" (IUCN 2002*), and *S. obscurus* is "highly rare ... critically imperiled" in Maryland (Maryland Wildlife and Heritage Division 1994*). The decline of both species is thought to reflect (1) gradual climatic changes since the last glaciation, (2) the subsequent reinvasion of lowland areas by the more ubiquitous Eastern Cottontail (*Sylvilagus floridanus*) (Chapman et al. 1992), and (3) destruction, fragmentation, and maturation of habitat (Barbour and Litvaitis 1993; Probert and Litvaitis 1996).

Few investigators (Chapman and Paradiso 1972; Chapman and Morgan 1973; Chapman et al. 1977; Chapman and Stauffer 1981; Spencer 1985) have studied the ecology of the Appalachian Cottontail in Maryland and West Virginia. No study has defined home ranges of *S. obscurus* in any part of its range. Home ranges of *S. transitionalis* in Connecticut estimated using live trapping and mark-recapture measured 0.2–0.7 ha (Dalke 1937). By contrast, home ranges of *S. floridanus* determined using radiotelemetry range from 1.0–2.8 ha (Chapman et al. 1982; Dixon et al. 1981), and males generally have larger home ranges than females (Trent and Rongstad 1974).

Habitat of Appalachian Cottontails in southeast Virginia has been described as six- to seven- year-old clear cuts (Blymer 1976). In Maryland, however, this species is reportedly limited to high elevations (above 570 m) in habitats containing conifers and ericaceous (heath-like) vegetation (Chapman and Paradiso 1972; Chapman and Stauffer 1981). Barbour and Litvaitis (1973) found New England Cottontails in New Hampshire by searching sites with dense understory cover.

Habitat fragmentation and patch size are important considerations in habitat requirements. *S. obscurus* in western Maryland may not survive and reproduce in forested areas less than about 20 000 ha (Chapman et al. 1977). New England Cottontails on small patches (< 2.5 ha) had lower survival rates than rabbits on large patches (> 5.0 ha) owing to quality of habitat and forage (Barbour and Litvaitis 1993; Villafuerte et al. 1997). On a larger scale, New England Cottontails had lower survival rates in fragmented landscapes than in more even landscapes (Brown and Litvaitis 1995).

The objectives of our study were to determine size and habitat characteristics of home-ranges of Appalachian Cottontails in western Maryland. We tested the following hypotheses: (1) home ranges are similar in size (~0.2–0.7 ha) to those reported previously for *S. transitionalis;* (2) males have larger home ranges than females; (3) rabbits select home ranges with extensive coniferous and ericaceous vegetation; and (4) rabbits use microhabitats within the home range with the greatest amount of understory (concealment) cover.

* See Documents Cited section

Study Area and Methods

Study sites

Our study was conducted in the Savage River State Forest, Garrett Co., Maryland. The forest encompasses about 21 400 ha of woodlands and is one of the largest blocks of forest remaining in Maryland. It is primarily an even-aged, second-growth forest, about 70 to 90 years old. *Sylvilagus obscurus* is considered rare in the forest (Maryland Department of Natural Resources 1992*). Study sites were chosen on the basis of accessibility, reports of historical inhabitance by *S. obscurus* (Chapman and Morgan 1973; R. P. Morgan, personal communication; and S. A. Olcott, personal communication), the presence of habitat broadly characteristic of habitat used by *S. obscurus* (e.g., high elevations and abundant ericaceous vegetation), lack of open corridors through which *S. floridanus* could easily invade, and the presence of rabbit tracks and pellets.

Our study site was located north of Turkey Lodge Ridge, 3 km east of New Germany State Park (79°05'W, 39°37'N). Elevation ranged from 730–820 m. The site was classified as predominantly mature mixed-oak forest; however, abundant patches of nine-year-old clear cuts existed (J. Hare personal communication). Mature stands were dominated by Chestnut, White, and Red oaks (*Quercus prinus, Q. alba,* and *Quercus* spp.), Red Maple (*Acer rubrum*), and Black Birch (*Betula lenta*), with an understory dominated by Mountain Laurel (*Kalmia latifolia*) and blueberries (*Vaccinium* spp.). Early successional stages after clearcuts were dominated by Mountain Laurel, blueberries, and Blackberry (*Rubus alleganiensis*). Conifers present were Eastern Hemlock (*Tsuga canadensis*) and White Pine (*Pinus strobus*).

Procedure

Rabbits were captured with wooden box traps (18 × 22 × 60 cm) baited with apple slices. Traps were placed in areas where rabbit tracks and pellets were found. Trapping was performed from December 1994 to mid-March 1995. We distinguished *S. obscurus* from *S. floridanus* using morphological characteristics designed originally to distinguish *S. transitionalis* from the latter (Litvaitis et al. 1991).

Individuals were anesthetized by intramuscular injection of ketamine hydrochloride (30–45 mg/kg body mass) and then ear-tagged (National Band and Tag Co., Newport, Kentucky). Blood samples were taken from the ear, centrifuged to isolate plasma, and stored at -80° C. Positive species identifications were obtained by electrophoretic analysis/isoelectric focusing of blood serum proteins (Chapman and Morgan 1973; Sommer 1997) using Ampholine PAGplates (Pharmacia LKB Biotecknology, Uppsala, Sweden) with pH gradients of 5.5 to 8.5.

Adults (>750 g for females and >800 g for males: Chapman and Morgan 1973) were fitted with collar-mounted transmitters (Lotek Engineering, Inc., Newmarket, Ontario, Canada). We tracked radio-collared individuals using a hand-held H-antenna (Lotek Engineering, Inc., Newmarket, Ontario). Rabbits were approached on foot. Precise locations were confirmed most often by direct observation of the subject, or by carefully monitoring the strength of the radio signal to determine the cluster of vegetation in which the subject was located. Rabbits initially remain motionless when threatened (Whitaker 1980) so rabbit locations did not likely represent locations to which they fled due to our approach.

We obtained an average of two locations per week, for durations of 2.5–5 months for individual rabbits. Rabbits were monitored between February and July 1995, i.e., during the breeding season, which extends from February to September. Days were divided into six 4-hour blocks, and equal numbers of locations were obtained for each time block that contained daylight hours.

Universal-Transverse-Mercator-grid coordinates used to calculate home-range sizes were determined for each location using GPS (Trimble Navigation Plus, Trimble Navigation, Ltd., Sunnyvale, California). A total of 180 readings was taken at each location and then averaged using the software PATHFINDER (Trimble Navigation, Ltd., Sunnyvale, California). Coordinates had mean error polygons of 0.34 ha, as determined by obtaining 35 sets of GPS coordinates for seven known points. This error was consistent with errors in home-range estimates for mammals with home-range sizes similar to that of Appalachian Cottontails (*S. aquaticus*, Kjolhaug and Woolf 1988; *Citellus variegatus,* Ortega 1990; *Marmota flaviventris,* Salsbury and Armitage 1994; *Marmota monax,* Swihart 1992; *Sylvilagus floridanus,* Trent and Rongstad 1974).

We examined selection and use of home ranges at two spatial scales (i.e., macrohabitat and microhabitat). We quantified habitat variables within 1-m radius plots at rabbit locations and random locations both within and outside home ranges. Random plots within home ranges were located at random distances 15-35 m apart along systematically placed transects. Random plots outside home ranges (i.e., outside areas where rabbits were located or rabbit tracks or pellets were observed) were located similarly along transects extending a distance equal to approximately one-half the diameter of the home range. Depending on the individual, the number of random plots within and outside a home range ranged from 20–38.

Continuous and ordinal variables were converted to categorical variables. Habitat variables included understory stem density (0, 1–20, 21–50, 51–100, or >100 stems of any plant >0.5 m tall and <7.5 cm dbh); distance to concealment cover (< 2, 2–5, 5–10, or >10 m from a clump of understory vegetation at least 1 m^2 in area that provided > 50% visual obstruction: Barbour and Litvaitis 1993); percent

vegetative cover (< 20, 20–< 40, 40–< 60, 60–< 80, 80–100) at 0.5-m intervals up to 1.5 m above substrate; percent canopy closure (0–30, 31–60, 61–80, 81–94, 95–100); percent ground cover (< 20, 20–< 40, 40–< 60, 60–< 80, 80–100) of rocks, logs, and stumps; slope (< 8, 8–16, 17–24, and > 24°); and dominant (i.e., that which constituted the greatest percent cover) overstory and understory species. Percent vegetative cover up to 1.5 m was estimated using a vegetation profile board (Nudds 1977) constructed from fabric. Percent canopy closure was estimated using a densiometer (Forest Densiometers, Arlington, Virginia). Ground cover was estimated using an ocular tube (diameter = 7.5 cm: James and Shugart 1970).

Estimation of home range

We measured home ranges using the minimum convex polygon (MCP: Mohr 1947) and adaptive kernel (AK: Worton 1989) methods. In addition to maximum (100%) MCP home ranges, we determined areas based on utilization distributions containing 95% of points using MCP and AK to permit comparisons with other studies. Home ranges were represented by medians rather than means because of sample size (n = 8).

We calculated home range using CALHOME (Kie et al. 1994*). CALHOME uses the Epanechnikov kernel and selects an optimum smoothing parameter that results in the lowest least-squares cross-validation (LSCV) score (Worton 1989). However, we reduced smoothing parameters to 60% of the selected value because the data were not normally distributed and this strategy prevented partitioning of home ranges into unconnected parcels (Kie et al. 1994*).

We assumed locations to be independent because sufficient time (> 24 h) was allowed between locations for an animal to move from one end of its home range to another (White and Garrott 1990). The number of radio-telemetry locations was assumed to be adequate for determining home-range size when an asymptote was reached in a plot of home-range size against cumulative number of locations (Bowyer et al. 1995). We used a Mann-Whitney *U*-test (SYSTAT® 9, Statistics I, SPSS, Inc., Chicago, IL; Zar 1999) to determine whether 100% MCP home ranges differed between males and females.

Site selection and use of home range

We used heterogeneity G-tests to determine whether rabbits belonged to the same statistical population with respect to habitat. If all rabbits belonged to the same statistical population relative to any single habitat variable, we applied chi-square goodness-of-fit tests to data pooled from all rabbits (Zar 1999). These tests indicated whether habitat within home ranges differed from that outside home ranges (site selection) and whether habitat available within home ranges differed from that used (i.e., at rabbit locations).

When rabbits did not belong to the same statistical population for a habitat variable, we used log-likelihood goodness-of-fit tests (Zar 1999) to assess site selection and use of habitat. Bonferroni confidence intervals were then used to determine which categories of each habitat variable were selected or avoided (represented more or less often than expected by chance) by individuals (Neu et al. 1974). When the expected value for a certain category of a habitat variable was <1.0, we combined values of adjacent (in magnitude) categories of the variable to prevent bias of the *G*-statistic (Zar 1999). All statistical tests were considered significant at $P < 0.05$.

Results

Home range

Eight Appalachian cottontails (four males and four females) were located from 20–38 times each between February and July 1995 (Table 1). Home ranges were large and variable. Median 100% MCP home range was 5.4 ha; home-range size did not differ between the sexes ($U = 2.000$, $p = 0.081$). Median 95% MCP and AK home ranges were 4.3 and 4.7 ha respectively.

TABLE 1. Home ranges (ha) of adult female (F) and male (M) Appalachian Cottontails in the Savage River State Forest, Garrett County, Maryland, as determined by 100% and 95% minimum convex polygon (MCP) and 95% adaptive kernel (AK) estimates.

Rabbit	Number of locations	Dates of study	100% MCP	95% MCP	95% AK
F1	32	1 April-10 July 1995	2.8	2.4	3.3
F2	34	24 February-10 July 1995	1.7	1.4	1.4
F3	38	17 February-10 July 1995	6.5	5.4	5.4
F4	22	28 April-10 July 1995	4.3	3.1	2.6
M1	20	12 March-9 June 1995	6.9	5.6	5.4
M2	48	17 February 1994-10 July 1995	4.2	3.2	4.0
M3	30	3 March-10 July 1995	9.0	8.3	8.5
M4	38	17 February-10 July 1995	9.0	6.5	5.3

Site selection and use of home range

Considerable individual variability characterized site selection and use of home ranges. Despite this variation, we attempted to recognize common habitat associations of rabbits by noting modal responses; i.e., selection or avoidance of a certain category of a habitat variable by four or more of the eight rabbits.

Rabbits were located across the entire range of elevations (730–820 m) of the study site. Eastern Cottontails occupied nearby fields, but none occurred at our study site.

Heterogeneity *G*-tests indicated that rabbits did not belong to the same statistical population with respect to site selection, except for ericaceous and coniferous vegetation. Random locations within home ranges had no more ericaceous vegetation (n = 253, χ^2 = 0.15, P>0.50) or conifers (n = 253, χ^2 = 1.94, P > 0.10) than random locations outside home ranges.

In their selection of home ranges, rabbits avoided areas with steep slopes (>25°; Figure 1A) and those with low amounts of understory cover (<40% from 0–1.0 m and <80% from 1.1–1.5 m; Figure 1B-D). Home ranges had greater amounts of understory cover (>80% from 0–0.5 m and 1.1–1.5 m, and >60% from 0.6–1.0 m above the substrate; Figure 1B-D) than the surrounding landscape.

Five rabbits (four males, one female) had some area of their home ranges bounded by agricultural fields. Some portions of the home ranges of three rabbits (one female, two males) were bounded by a stream in open, mature woodland. The home ranges of two individuals (one female, one male) were bounded, in part, by pine plantations with open understory. A steep slope (>25°) constituted some of the boundary of the home range of one male.

Rabbits disproportionately used sites in close proximity (<2 m; Figure 2A) to concealment cover, and those with incomplete canopy closure (< 95%; Figure 2B) and *R. alleganiensis* as the dominant shrub species. Rabbits avoided microhabitats >10 m from concealment cover (Figure 2A), those with ≥ 95% canopy closure (Figure 2B), and those with low stem density (< 20 stems/1-m radius plot; Figure 2C).

Discussion

Home ranges were highly variable in size but consistently much greater than those previously reported for *S. transitionalis* (Dalke 1937). Although male home ranges were not statistically larger than those of females, power analysis (Conover and Iman 1981) indicated a low probability (φ = 0.342, $P < 0.30$) of detecting any statistically significant differences between the sexes in home-range size because of sample size.

The duration of a study could affect home-range estimates if rabbits shift their home ranges because of food availability, the distribution of potential mates, or the presence of predators (e.g., White and Garrott 1990). However, we monitored rabbits for 2.5–5 months, consistent with durations of other home-range studies of *Sylvilagus* spp. (Chapman and Trethewey 1972; Trent and Rongstad 1974; Dixon and Chapman 1980; Kjolhaug and Woolf 1988). We did monitor rabbits during the breeding season when males travel in search of mates. However, it is unlikely that we overestimated home ranges because we monitored adults only, and *S. obscurus* may establish permanent home ranges shortly after maturity, as Forys and Humphrey (1996) found for *S. palustris hefneri*.

We observed some home-range boundaries along edges of preferred habitat where comparatively little understory cover existed. Similarly, J. A. Litvaitis (personal communication) observed home-range boundaries of *S. transitionalis* consistently coinciding with boundaries of habitat patches in New Hampshire. Some adjacent habitats (e.g., agricultural fields) in our study would seem to constitute hard edges (Stamps et al. 1987) that inhibit movement and dispersal, illustrating how fragmentation of habitat could limit the distribution of *S. obscurus*. Rabbits also may have avoided steep slopes because traveling and resting may be difficult in such terrain.

Our hypothesis that rabbits would locate home ranges in areas with the most extensive coniferous and ericaceous cover was not supported by the data. Ericaceous vegetation and conifers may be possible, but not necessary components of Appalachian Cottontail habitat. Blymer (1976) reported no ericaceous or coniferous vegetation in a six- to seven-year-old clearcut of early successional hardwoods densely populated with Appalachian Cottontails. The habitat of New England Cottontails in New Hampshire had dense understory vegetation dominated by *A. rubrum, Corylus cornuta, Viburnum* spp., *Rubus* spp., and *T. canadensis,* but no ericaceous species (Barbour and Litvaitis 1993; Brown and Litvaitis 1996). The presence of dense understory concealment cover seems to be a more important indicator of where Appalachian Cottontails occur in western Maryland than any species of vegetation.

Most ecological studies of *S. transitionalis* and *S. obscurus* have described large-scale characteristics of forests or patches of habitat (e.g., Fay and Chandler 1955; Blymyer 1976; Brewer 1980; Brown and Litvaitis 1995; Spencer and Chapman 1986). Barbour and Litvaitis (1993) found that *S. transitionalis* on habitat patches >5.0 ha used sites with dense understory cover and sites close to cover. Our results that Appalachian Cottontails selected home ranges with dense understory cover and used sites near concealment cover are consistent with these findings. Smith (1997) proposed that greater visual acuity (i.e., larger eye size and the ability to detect predators at greater distances) in *S. floridanus* enables the

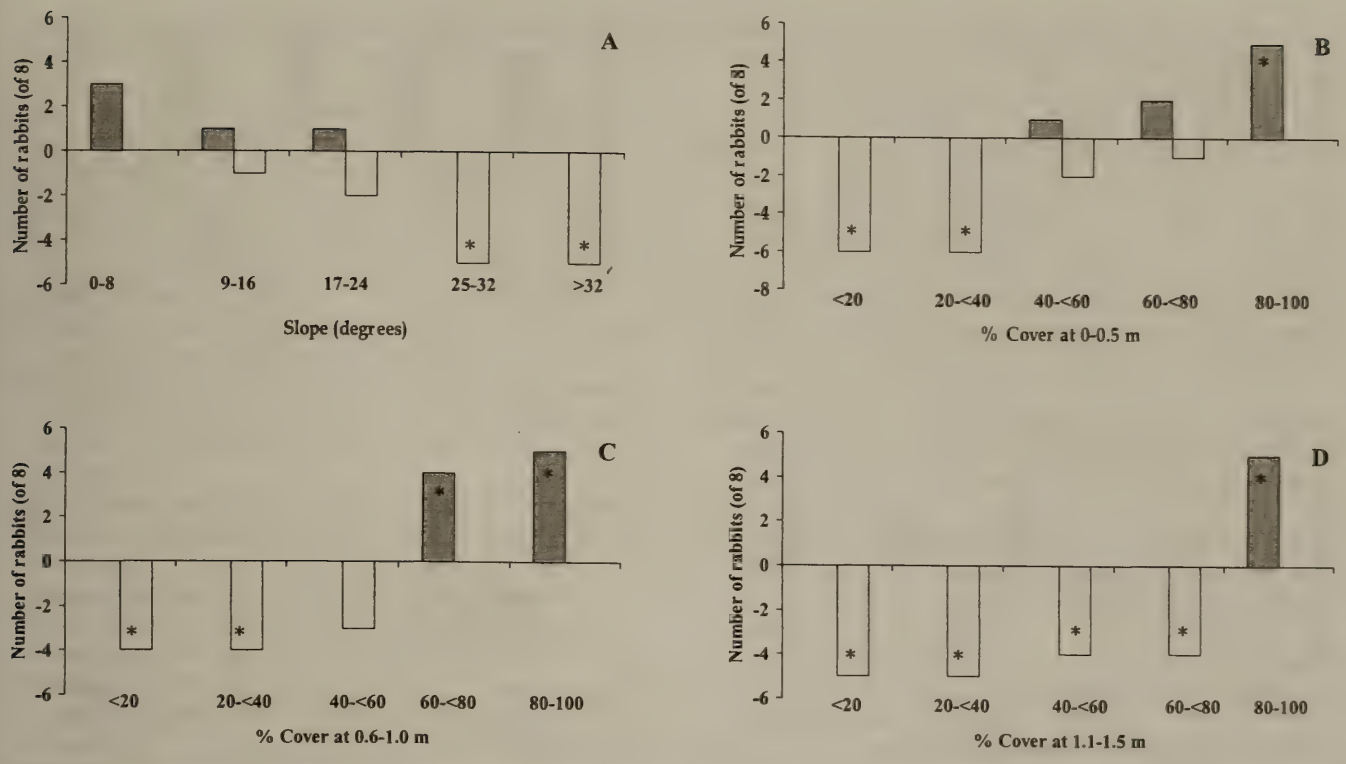

FIGURE 1. Numbers of western Maryland Appalachian Cottontails (of eight total) that selected (shaded) and avoided (clear) certain categories of habitat variables (A-D) in the site selection of home ranges. Selection and avoidance were considered significant at $P < 0.05$. Individual rabbits may have selected more than one category. Modal responses (*) are recognized if four or more individuals selected or avoided a particular category.

species to exploit open habitats where *S. transitionalis* (and presumably *S. obscurus*) suffers higher risks.

Our hypothesis that *S. obscurus* uses home-range sites with the greatest amount of understory cover was partially supported by the avoidance of sites with low stem density. Lack of selection for high percent understory cover may have been due to two factors: (1) fairly homogeneous expanses of dense understory that provided adequate cover throughout much of the home range, and (2) differential seasonal use of the home range not detected by our methodology. These results illustrate the importance of examining habitat preferences on a variety of spatial and temporal scales.

The avoidance of home-range microhabitat with low stem densities may be related to the selection of sites with *R. alleganiensis*. *R. alleganiensis* and *K. latifolia* were dominant in areas with high stem densities. Places with densely populated stems may be more difficult for predators to navigate. Moreover, *S. obscurus* eats *R. alleganiensis* (Spencer and Chapman 1986). The evergreen *K. latifolia* provides cover during winter. Studies during seasons when leaves are present and absent are needed to determine if seasonal variability exists in the selection of habitat by *S. obscurus*.

Grasses and sedges make up the majority of the summer diet of *S. obscurus*, but woody material is the main component of its winter diet (Spencer and Chapman 1986). Sites with high percentages of canopy closure were probably avoided because understory productivity that provides necessary cover and food (e.g., Mountain Laurel, Rhododendron, blueberries, and grasses) is reduced in such conditions.

The considerable individual variation we found in home-range size, site selection, and microhabitat use by rabbits illustrates the importance of analyzing such variation in addition to measures of central tendency and interpopulation variation in traits (Hayes and Jenkins 1997; Holmes and Sherry 1997). Individuals are potentially constrained by genetics, developmental history, age, experience, and their immediate surroundings. Much of the variability in our study probably reflects variability in the immediate environment (i.e., habitat) because only adults in the same area were studied.

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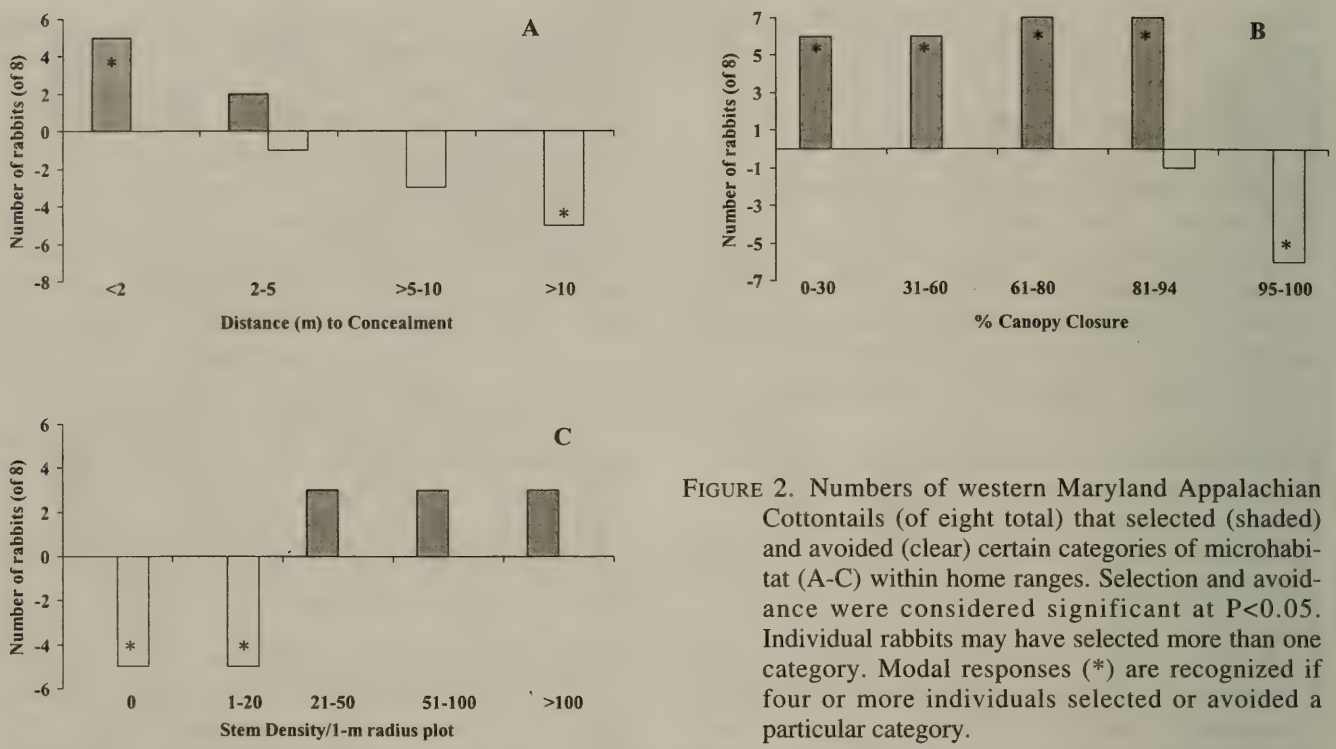

FIGURE 2. Numbers of western Maryland Appalachian Cottontails (of eight total) that selected (shaded) and avoided (clear) certain categories of microhabitat (A-C) within home ranges. Selection and avoidance were considered significant at $P<0.05$. Individual rabbits may have selected more than one category. Modal responses (*) are recognized if four or more individuals selected or avoided a particular category.

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Distribution of Blacknose Dace, *Rhinichthys atratulus*, in Nova Scotia

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The Blacknose Dace, *Rhinichthys atratulus*, is the most commonly misidentified minnow (Cyprinidae) in Nova Scotia. It is the only minnow native to this province having non-protractile premaxillaries. The Blacknose Dace, in Nova Scotia, is restricted to portions of The Northumberland Strait and Bay of Fundy watersheds with headwater streams originating on the Cobequid Mountains. Fifty-five localities are documented for which collections have been made. Thirty-seven additional localities where no Blacknose Dace were found are also mapped.

Key Words: Blacknose Dace, *Rhinichthys atratulus*, external characters, distribution, habitat, Cobequid Mountains, Northumberland Strait Drainage, Bay of Fundy Drainage, Nova Scotia.

The Blacknose Dace, *Rhinichthys atratulus* (Robins et al.) [snout fish clothed in black] (Scott and Crossman 1973) is a small minnow (Cyprinidae) having an elongate, streamlined, body (Figure 1). The snout slightly overhangs the mouth (subterminal mouth). The pectoral fins are held in a horizontal position for balance in moderate flow and riffles. It is an agile swimmer adapted for living in shallow streams. The most diagnostic external character is the presence of non-protractile premaxillaries, no groove between the upper lip and snout (Figure 2). All other minnows, native to Nova Scotia, have protractile premaxillaries, with a groove extending across the midline of the snout. The absence or presence of a groove is easily recognizable using a hand lens.

Live Blacknose Dace in Nova Scotia have a prominent, satiny-black, lateral stripe which extends around the snout, through the eyes, becomes broader on the sides of the head, continues along the trunk and caudal peduncle, ending in a blotch which streaks the base of the mid-caudal fin rays. The back is typically a light copper-orange, finely speckled with grey. The backs of a few individuals in Debert and Folly rivers, Bay of Fundy Drainage, were noted to be light iron-pyrite yellow, finely speckled with grey. This speckling extends down almost to the black stripe, thus leaving a narrow, lustrous, copper-orange, or iron pyrite-yellow, stripe bordering the black stripe. One very dark adult male from Pugwash River was black on the back, which was continuous to the black stripe and lacking a lustrous border. The lower sides are pearly-white becoming silvery-white on the belly.

Sexually mature males display a reddish blush on the fins Gilhen 1974, particularly the pectoral fins. When males are in breeding condition and courting females, the red colour becomes so intense that the black lateral stripe is no longer discernable. However, within a few minutes of a male being removed from the spawning site and placed in an aquarium it regains the black stripe leaving only the fins and sides blushed in red.

The average total length of adult Blacknose Dace collected in Nova Scotia is 58.5 millimeters, ranging from 50 to 72 mm (n = 71). Scott and Crossman (1973) gave the average length as 64 mm.

Distribution

The Blacknose Dace is found in eastern and central Canada from northwestern mainland Nova Scotia, west through New Brunswick, southern Quebec and Ontario, in Lake of the Woods but not northeast of Lake Superior, northwest to central Manitoba; and southward in the United States, on both sides of the Appalachian Mountains, to Georgia, Alabama and Mississippi (Scott and Crossman 1973; Coad et al. 1995).

In Nova Scotia, *R. atratulus* is restricted to watersheds with headwater streams on the Cobequid Mountains of the northern mainland (Figure 3). The streams on the north side, which empty into the Northumberland Strait, where we found Blacknose Dace are (from west to east) Shinimicas River (SHR), River Philip (RP), Pugwash River (PUR), Wallace River (WR), French River (FR), Waughs River (WAR) and River John (RJ) (Appendix 1). Streams on the south side which empty into the Bay of Fundy are, from west to east, Maccan River (MAR), Hebert River (RH), Moose River (MR), Portapique River (PR), Great Village River (GVR), Folly River (FR), Debert River (DR), North River (NR) and Salmon River (SR) (Appendix 2).

Habitat

The Blacknose Dace in Nova Scotia inhabits only those watersheds having first order streams draining the north or south faces of the Cobequid

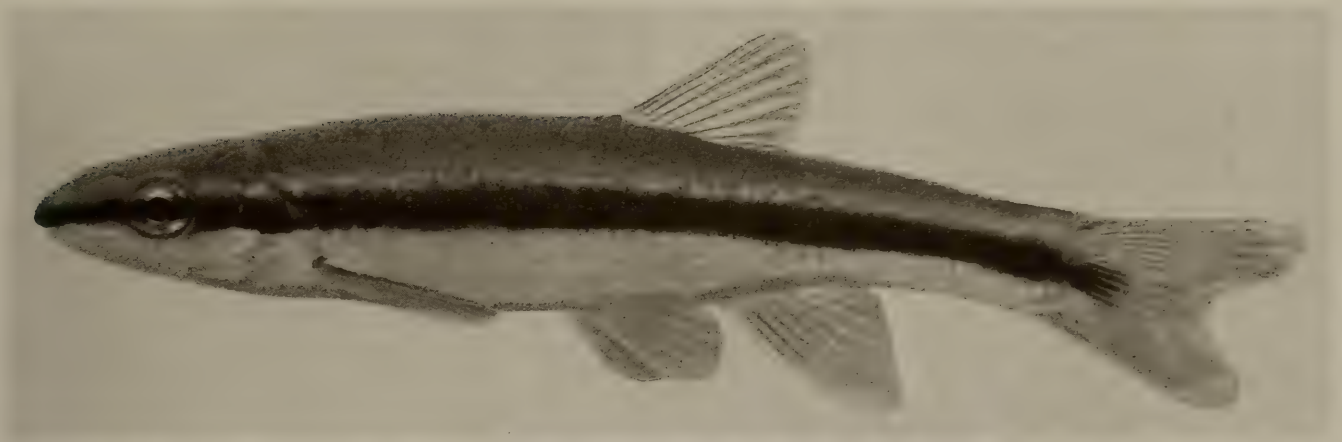

FIGURE 1. A computer-enhanced photograph of a living adult male Blacknose Dace, *Rhinichthys atratulus*, from Christie Brook, a tributary of Salmon River, Bay of Fundy Drainage, Nova Scotia, 7 May 1998 (Negative Number-24,377 frame # 20).

Mountains. Natal rivers and some of their tributaries, typically have extensive shallow sections with riffles. The clear, cool water flows at a moderate rate over gently-sloping hard bottom. *R. atratulus* shares this specific habitat with Brook Trout, *Salvelinus fontinalis*, in brooks (Figure 4) and Atlantic Salmon parr, *Salmo salar*, in rivers (Figure 5). The described habitat helps to explain why this stream fish is not found in all watersheds originating on the Cobequid Mountains. We did not find Blacknose Dace in streams which cascade or in slow, deep, soft-bottomed sections, such as extensive still-waters or in parts which meander through bogs. When we checked marginal waters, such as quiet shallow inlets and at the mouths of slow tributaries, of streams where *R. atratulus* were found we observed mixed schools of cyprinids including juveniles of Blacknose Dace, Common Shiner (*Luxilus cornutus*), Northern Redbelly Dace (*Phoxinus eos*), and Creek Chub (*Semotilus atromaculatus*), and other freshwater species such as juvenile White Sucker (*Catostomus commersoni*), and Threespine Stickleback (*Gasterosteus aculeatus*). When we checked streams at the periphery of the range of Blacknose Dace, such as Paradise Brook (Tidnish River watershed), and West River (Pictou watershed), where no Blacknose Dace were found, the niche was occupied by Lake Chub, *Couesius plumbeus*. The mis-named Lake Chub is also an elongate streamlined minnow well-adapted to living in shallow streams. This could explain why juvenile Lake Chub have been mis-identified as Blacknose Dace.

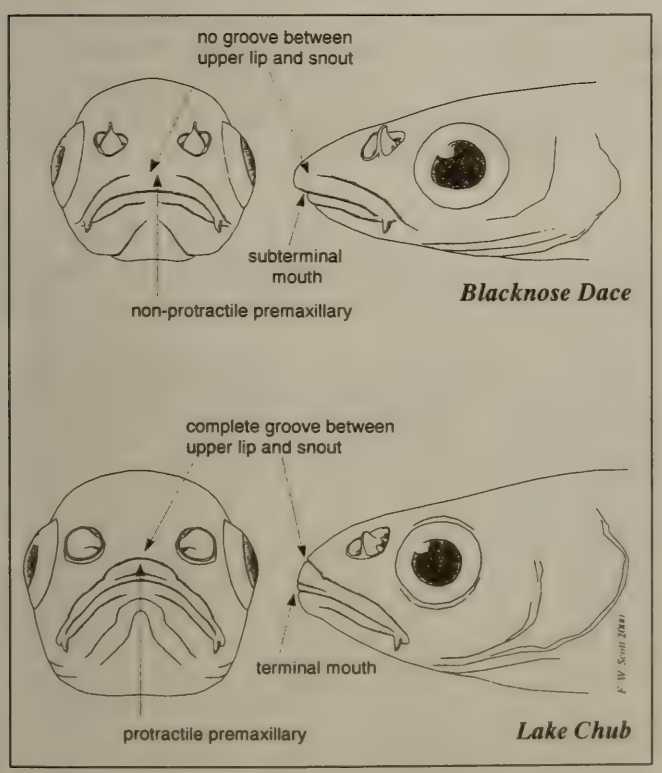

FIGURE 2. Sketch showing non-protractile premaxillaries of a Blacknose Dace, *Rhinichthys atratulus*, from Christie Brook, a tributary of Salmon River, Bay of Fundy Drainage, Nova Scotia (NSM12635 (.1)) and protractile premaxillaries of a Lake Chub, *Couesius plumbeus*, from Paradise Brook, a tributary of Tidnish River, Northumberland Strait Drainage, Nova Scotia (NSM12665 (.1)).

Discussion

In distribution, the Blacknose Dace is one of the most restricted of the freshwater fishes native to Nova Scotia. Although it can be identified by checking the non-protractile premaxillaries, it is the most commonly misidentified minnow in this Province. This is a result of the lack of attention to non-game fishes during fish surveys for environmental assessments. In Nova Scotia, when such faunal surveys are undertaken, there is no requirement for the collection of voucher specimens of non-game fishes or their deposition in a repository collection. The Nova Scotia Museum of Natural History has an extensive fish collection and is one institution where environ-

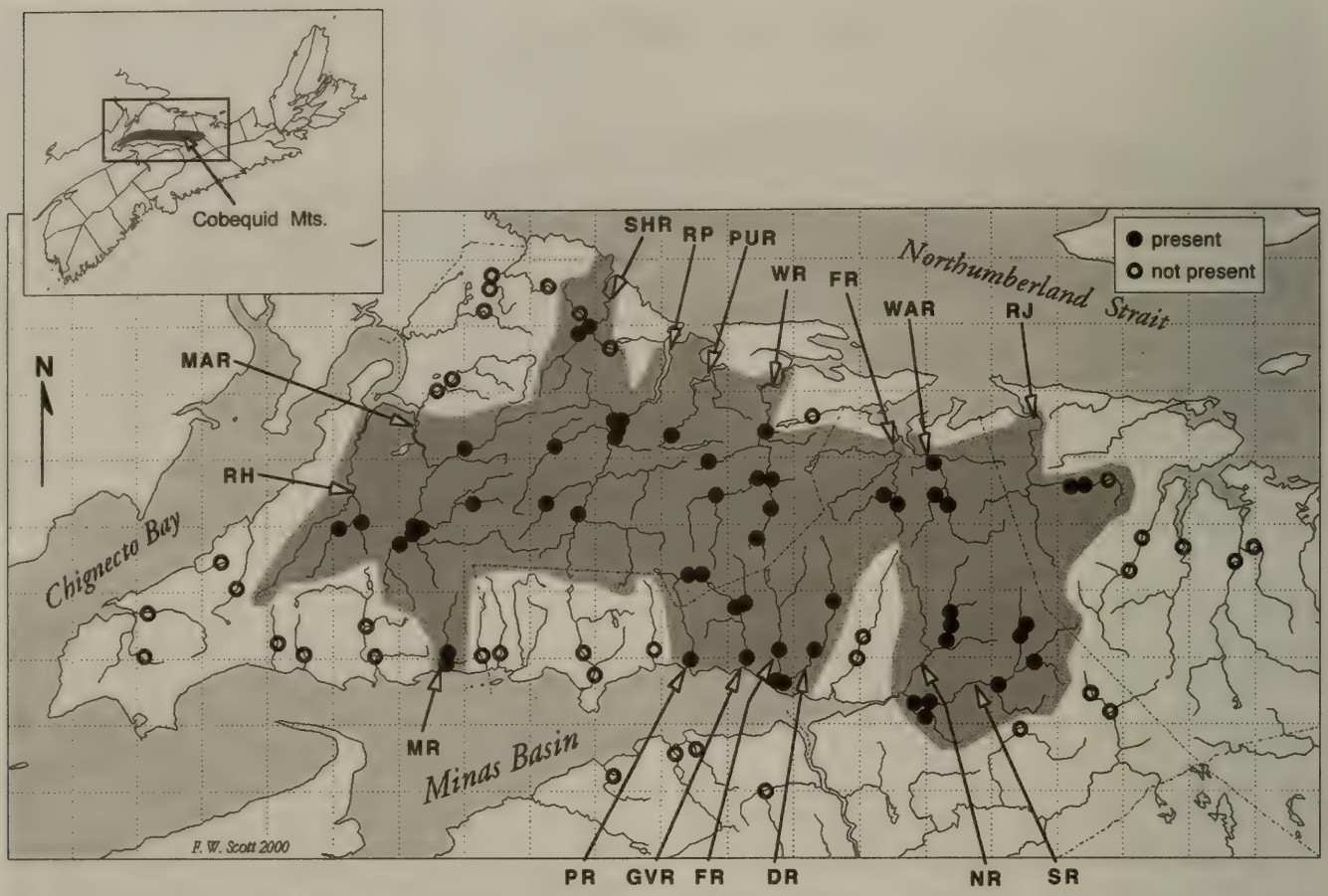

FIGURE 3. Distribution of Blacknose Dace, *Rhinichthys atratulus*, in Nova Scotia. Not Present, represented by open circles on the map, means localities where Blacknose Dace were looked for but not found. In the Northumberland Strait Drainage the letters SHR refers to Shinimicas River; RP, River Philip; PUR, Pugwash River; WR, Wallace River; FR, French River; WAR, Waughs River; and RJ, River John (see Table 1). In the Bay of Fundy Drainage, MAR refers to Maccan River; RH, River Hebert; MR, Moose River; PR, Portapique River; GVR, Great Village River; FR, Folly River; DR, Debert River; NR, North River and SR, Salmon River, (see Table 2).

mental assessment reports are reviewed for completeness and accuracy and the identification of specimens can be verified.

Errors in identification of Blacknose Dace date back to 20 July1941 when C. F. Allen mis-identified three Northern Redbelly Dace, *P. eos*, from Grand Lake, Halifax County, as Striped Dace, *Rhinichthys atronasus*, the common and scientific names in use at that time for Blacknose Dace (Scott and Crossman 1973). This record was repeated by Davis (1981).

There are a number of other incorrect records, also from localities outside the range for Blacknose Dace in Nova Scotia. We suspect Blacknose Shiner, *Notropis heterolepis*, have been incorrectly identified as Blacknose Dace in a report on Lake Egmont (Parker 1994). Another such record is Anonymous (1998) in which Blacknose Dace was reported from 35 localities across the northern mainland; 11 are in north-eastern Nova Scotia well outside its confirmed range. Between 1972 and 2000, J. G. investigated streams between West River Pictou, Pictou County; and St. Marys River, Guysborough County, for freshwater fishes and did not find Blacknose Dace at any of the sampled sites. Juvenile Creek Chub were observed in the St. Marys River that have a prominent black lateral band which extends onto the head, possibly accounting for previous confusion.

During a study of the food of mergansers, White (1957) did not find Blacknose Dace in the stomachs of these fish-eating birds from three streams in the northeast mainland including Moser River, East River St. Marys and West River St. Marys. He did, however, find Blacknose Dace in stomachs of mergansers at Wallace River (WR), Maccan River (MAR), River Hebert (RH) and River Philip (RP) of the Carboniferous area of mainland Nova Scotia where we also found *R. atratulus* (Figure 3).

Blacknose Dace were first collected in Nova Scotia at Higgens Brook, a tributary of Wallace River (WR), by A. G. Huntsman on 30 July 1937 (Appendix 1). The second collection of *R. atratulus* for this Province was at McPherson Bridge, Shinimicas River (SHR), by an unknown collector, 13 September 1944. Both collections are from Northumberland Strait drainage of Nova Scotia and are in the Royal Ontario Museum (ROM), Toronto.

Dan A. Livingstone collected freshwater fishes in

FIGURE 4. Christie Brook, a tributary of Salmon River, Bay of Fundy Drainage, Nova Scotia, habitat where Blacknose Dace, *Rhinichthys atratulus*, White Sucker, *Catostomus commersoni*, Brook Trout, *Salvelinus fontinalis*, and Threespine Stickleback, *Gasterosteus aculeatus*, were recorded. Photograph taken on 13 August 1998 (Negative Number 24,379: Frame Number 2).

Nova Scotia over the four-year period 1947 to 1950. He also visited the Royal Ontario Museum and noted the collections of freshwater fishes from Nova Scotia. He did not find the two earlier samples of *R. atratulus*. These records are not mentioned by Scott and Crossman (1973) and may have been deposited ROM at a later date. Livingstone (1952), therefore, lists only the two localities, Shinimicas River (SHR) and River Philip (RP), for Blacknose Dace which he discovered during his 1950 survey.

FIGURE 5. Salmon River at road to Riversdale, Bay of Fundy Drainage, Nova Scotia, habitat where Blacknose Dace, *Rhinichthys atratulus*, White Sucker, *Catostomus commersoni*, young Rainbow Smelt, *Osmerus mordax*, Atlantic Salmon parr, Salmo salar and Threespine Stickleback, *Gasterosteus aculeatus*, were recorded. Photograph taken on 13 August 1998 (Negative Number 24,380: Frame Number 8).

In the summer of 1955 Francis R. Cook and John S. Erskine collected fishes in lakes and streams as they criss-crossed the mainland of Nova Scotia and added five new localities for Blacknose Dace. A collection of two specimens from Atkinson Brook in the River Hebert (RH) watershed on 30 July 1955 is the first record of *R. atratulus* for the Bay of Fundy Drainage (Cook 1961) (Appendix 2). A collection of one specimen on 1 August 1955 from a stream near Dewar (Angevine) Lake is believed to be from Flemming Brook, a small tributary of Wallace River (WR).

Most samples of Blacknose Dace in the fish collection of the Nova Scotia Museum of Natural History were collected between 1964 and the present, with the greatest sampling effort carried out by us during spring and summer of 1997 and 1998. A beach seine and pond dip net were effective in collecting specimens.

After four years collecting and observing freshwater fishes in Nova Scotia, Livingstone (1952) noted the largest number of species were found in Cumberland County and that the number of species diminishes to the east and south through the Province. He hypothesized that "This lack of range discontinuities indicates that complete destruction of the pre-Pleistocene fish fauna occurred during the glaciation of Nova Scotia, and that the species now here have repopulated the province since the recession of the ice sheet. The species abundance in the various regions indicates that they entered Nova Scotia by way of the Isthmus of Chignecto, not by some [southern] land bridge no longer existing." The distribution of the Blacknose Dace is one example used to support this hypothesis. The post-glacial recolonization of lakes and streams in Nova Scotia, however, is probably more complex than previously thought, and may involve westward migrations from Atlantic refugia (Howden et al. 1970; Marcogliese 1992; Nedeau et al. 2000).

Because recognition of distinct populations and peculiar distribution patterns of freshwater fishes in Nova Scotia probably holds clues to the post-Wisconsin Glaciation re-colonization in this Province it is important that we have a clear understanding of the distribution of each species in this Province. Today, however, the integrity of these interesting freshwater fish distribution patterns, particularly of forage fishes, such as minnows, is in jeopardy due to the introductions of foreign, predatory, freshwater game species, notably Chain Pickerel, *Esox niger*, and Smallmouth Bass, *Micropterus dolomieu*. Also, as Livingstone (1952) warned: "Similarly the salmonids will probably disappear from many of the marginal waters in which they now occur when faced with the competition of pikes and centrarchids".

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APPENDIX 1. A Chronological List of Blacknose Dace Collected in Watersheds of Northumberland Straight Drainage, Nova Scotia. ROM = Royal Ontario Museum, Toronto, Ontario; NMC = Canadian Museum of Nature, Ottawa, Ontario; NSM = Nova Scotia Museum of Natural History, Halifax, Nova Scotia.

Date Collected	Cat. No.	Locality (NS)	Watershed	Lat/Long	NS Map Reference	Collected by	No. of Specimens
30 July 1937	ROM22349	Higgins Brook, Wallace River	Wallace River (WR)	45° 35' 50"N, 63° 33' 45"W	22A5,L8	A. G. Huntsman	6
13 September 1944	ROM40503	Shinimicas River, at McPherson Bridge	Shinimicas River (SHR)	45° 52' 23"N, 63° 54' 29"W	18C2,P7	Unknown	25
23 August 1950	NMC79-0710	Branch of Shinimicas River, Cumberland Co.	Shinimicas River (SHR)	45° 52' 23"N, 63° 54' 29"W	18C2,P7	Dan A. Livingstone	10
24 August 1950	NSM950-Z-55	River Philip, Cumberland Co.	River Philip (RP)	45° 41' 35"N, 63° 53' 10"W	18D3,G16	Dan A. Livingstone	Not Recorded
1 August 1955	NSM955-Z-18	Stream near Dewar (Angevine) Lake, Cumberland Co. Probably Flemming Brook, Cumberland Co.)	Wallace River (WR)	45° 42' 55"N, 63° 34' 35"W	22A3,M14	Francis R. Cook John S. Erskine	1
2 August 1955	NSM955-Z-19	French River at Oliver, Colchester Co.	French River (FR)	45° 39' 30"N, 63° 19' 15"W	22C4,L10	Francis R. Cook John S. Erskine	22
7 August 1955	NSM955-Z-20	Black River at road to Salt Springs Station, Cumberland Co.	River Philip (RP)	45° 41' 10"N, 64° 00' 32"W	18C4,G7	Francis R. Cook John S. Erskine	12
8 August 1955	NSM955-Z-21	Pugwash River at Hansford, Cumberland Co.	Pugwash River (PUR)	45° 43' 13"N, 63° 45' 43"W	18E3,F14	Francis R. Cook John S. Erskine	4
30 May 1964	NSM964-Z-4	River Philip near Collingwood Corner, Cumberland Co.	River Philip (RP)	45° 36' 38"N, 63° 56' 12"W	18C4,M15	John Gilhen, John Chapman, Michael Gilhen	16
13 June 1964	NSM964-Z-7	West Branch Wallace River, Cumberland Co.	Wallace River (WR)	45° 38' 50"N, 63° 40' 14"W	18E4,N12	John Gilhen, John Chapman, Michael Gilhen	10
11 June 1977	NSM12600	River Philip, Cumberland Co.	River Philip (RP)	45° 44' 08"N, 63° 51' 52"W		Max Blouw	14
8 July 1983	NMC84-1428	Little River, Cumberland Co.	River Philip (RP)	45° 44' 08"N, 63° 51' 45"W	18D3,H11	Tom A. Edge	1
8 July 1983	NMC84-1429	Little River, Cumberland Co.	River Philip (RP)	45° 44' 08"N, 63° 51' 45"W	18D3,H12	Tom A. Edge	11
8 July 1983	NMC84-1430	Wallace River, Cumberland Co.	Wallace River (WR)	45° 39' 45"N, 63° 33' 25"W	22A4,M10	Tom A. Edge	9
18 July 1984	NSM984-Z-111	River Philip at Oxford Junction, Cumberland Co.	River Philip (RP)	45° 41' 35"N, 63° 53' 10"W	18D3,G16	John Gilhen	5

continued

APPENDIX 1. *Continued*

Date Collected	Cat. No.	Locality (NS)	Watershed	Lat/Long	NS Map Reference	Collected by	No. of Specimens
28 July 1986	NSM12601	Crawley Brook, Cumberland Co.	Wallace River (WR)	45° 41' 45"N, 63° 41' 48"W	18E3,L16	John Gilhen	1
2 September 1986	NSM12602	Wallace River above Provincial Picnic Park, Cumberland Co.	Wallace River (WR)	45° 37' 32"N, 63° 33' 25"W	22A4,M10	John Gilhen	4
26 May 1991	NSM10245	River Philip, Cumberland Co.	River Philip (RP)	45° 43' 15"N, 63° 52' 15"W	18D3,H13	John Gilhen	3
4 June 1997	NSM12604	Balmoral Brook, Colchester Co.	Waughs River (WAR)	45° 38' 53"N, 63° 11' 53"W	22D4,K11	John Gilhen Andrew Hebda	7
23 June 1997	NSM12608	Teed Brook, Cumberland Co.	Wallace River (WR)	45° 40' 10"N, 63° 33' 12"W	22A4,N9	John Gilhen Jason Taylor	1
23 June 1997	NSM12609	French River at Oliver, Colchester Co.	French River (FR)	45° 39' 30"N, 63° 19' 15"W	22C4,L10	John Gilhen Jason Taylor	1
28 June 1997	NSM12612	Toms Brook, Pictou Co.	River John (RJ)	45° 40' 38"N 63° 03' 46"W	22E4,L9	John Gilhen Karen Gilhen	4
28 June 1997	NSM12613	West Branch River John, Pictou Co.	River John (RJ)	45° 38' 23"N, 63° 02' 28"W	22E4,M12	John Gilhen Karen Gilhen	9
4 July 1997	NSM12617	MacKay Brook, Pictou Co.	River John (RJ)	45° 39' 03"N, 62° 57' 20"W	26A4,J12	John Gilhen	10
7 August 1997	NSM12621	Little River, Oxford area, Cumberland Co.	River Philip (RP)	45° 44' 08"N, 63° 51' 45"W	18D3,H11	John Gilhen Rebecca Flemming	11
7 August 1997	NSM12622	Shinimicas River, Cumberland Co.	Shinimicas River (SHR)	45° 52' 23"N, 63° 54' 29"W	18C2,P7	John Gilhen Rebecca Fleming	10
17 August 1997	NSM12623	Wallace River, Cumberland Co.	Wallace River (WR)	45° 40' 40"N, 63° 33' 30"W	22A4,M8	John Gilhen	5
17 August 1997	NSM12624	Donaldson Mill Brook, Colchester Co.	French River (FR)	45° 40' 32"N, 63° 21' 00"W	22C4,H8	John Gilhen	2
17 August 1997	NSM12625	French River at Oliver, Colchester Co.	French River (FR)	45° 39' 30"N, 63° 19' 15"W	22C4,L10	John Gilhen	8
20 August 1997	NSM12626	Waughs River, Colchester Co.	Waughs River (WAR)	45° 41' 36"N, 63° 14' 58"W	22C3,O16	John Gilhen	2
20 August 1997	NSM12627	Fourmile Brook, Colchester Co.	Waughs River (WAR)	45° 39' 20"N, 63° 13' 45"W	22D4,H11	John Gilhen	4
6 May 1998	NSM12634	River Philip at Route 104, Cumberland Co.	River Philip (RP)	45° 43' 15"N, 63° 52' 10"W	18D3,H12	John Gilhen	32
15 May 1998	NSM12640	Ash Brook, Cumberland Co.	Wallace River (WR)	45° 37' 08"N, 63° 39' 55"W	18E4,O15	John Gilhen	1
15 May 1998	NSM12641	Mountain Brook at Rose, Cumberland Co.	River Philip (RP)	45° 35' 30"N, 63° 46' 25"W	18D5,P8	John Gilhen	5

continued

APPENDIX 1. *Continued*

Date Collected	Cat. No.	Locality (NS)	Watershed	Lat/Long	NS Map Reference	Collected by	No. of Specimens
15 May 1998	NSM12642	River Philip at Tillits Creek, Cumberland Co.	River Philip (RP)	45° 40' 12"N, 63° 53' 46"W	18D4,F9	John Gilhen	10
22 May 1998	NSM12644	MacKay Brook, Pictou Co.	River John (RJ)	45° 39' 01"N, 62° 57' 17"W	26A4,J11	John Gilhen	5
22 May 1998	NSM12645	East Branch River John, at road to Black River, Pictou Co.	River John (RJ)	45° 40' 00"N, 62° 58' 45"W	26A4,G10	John Gilhen	24
22 May 1998	NSM12646	West Branch Wallace River at Greenville Station, Cumberland Co.	Wallace River (WR)	45° 38' 50"N, 63° 40' 14"W	18E4,N12	John Gilhen	3
30 May 1998	NSM12650	Rutledge Brook, Cumberland Co.	River Philip (RP)	45° 41' 38"N, 64° 00' 14"W	18C3,G16	John Gilhen	4
30 May 1998	NSM12653	River Philip at Oxford Junction, Cumberland Co.	River Philip (RP)	45° 41' 35'N, 63° 53' 10"W	18D3,G16	John Gilhen	10
30 May 1998	NSM12654	Wallace River at Route 104, Cumberland Co.	Wallace River (WR)	45° 40' 43"N, 63° 33' 33"W	22A4,M8	John Gilhen	20
2 August 1998	NSM12660	Pugwash River Hansford area, Cumberland Co.	Pugwash River (PUR)	45° 43' 13"N, 63° 45" 43"W	18E3,F14	John Gilhen	5
2 August 1998	NSM12661	River Philip, road to Williamsdale, (RP) Cumberland Co.	River Philip	45° 36' 26"N, 63° 56' 02"W	18C4,N15	John Gilhen	1

APPENDIX 2. A Chronological List of Blacknose Dace Collected in Watersheds of Bay of Fundy Drainage, Nova Scotia. Museum acronyms as in Table 1.

Date Collected	Cat. No.	Locality (NS)	Watershed	Lat/Long	NS Map Reference	Collected by	No. of Specimens
30 July 1955	NSM955-Z-17	Atkinson Brook, Cumberland Co.	River Hebert (RH)	45° 35' 45"N, 64° 24' 16"W	12E5,F7	Francis R. Cook John S. Erskine	2
28 May 1964	NSM964-Z-11	Sutherland Lake, Cumberland Co.	Portapique River (PR)	45° 31' 22"N, 63° 41' 00"W	18E5,M15	John Gilhen John Chapman Michael Gilhen	1
30 May 1964	NSM964-Z-8	Gleason Brook, Cumberland Co.	Portapique River (PR)	45° 32' 50"N, 63° 43' 05"W	18E5,J13	John Gilhen John Chapman, Michael Gilhen	4
8 July 1983	NMC84-1423	Southampton River, Cumberland Co.	Maccan River (MAR)	45° 35' 00"N, 64° 08' 30"W	18B5,G8	Tom A. Edge	4
8 July 1983	NMC84-1425	Little Forks River, Cumberland Co.	Maccan River (MAR)	45° 42' 10"N, 64° 08' 30"W	18B3,G15	Tom A. Edge	24
26 August 1987	NSM12603	Salmon River, Colchester Co.	Salmon River (SR)	45° 25' 45"N, 63° 04' 53"W	23E1,J16	Barry Sabean	2
4 June 1997	NSM12605	North River, Colchester Co.	North River (NR)	45° 29' 38"N, 63° 12' 45"W	23D1,J9	John Gilhen Andrew Hebda	2
23 June 1997	NSM12606	Debert River, Colchester Co.	Debert River (DR)	45° 26' 15"N, 63° 27' 36"W	23B1,K15	John Gilhen Jason Taylor	8
23 June 1997	NSM12607	Folly River, Colchester Co.	Folly River (FR)	45° 26' 34"N, 63° 31' 37"W	23A1,O14	John Gilhen Jason Taylor	2
23 June 1997	NSM12610	North River at McCallum Settlement, Colchester Co.	North River (NR)	45° 29' 38"N, 63° 12' 45"W	23D1,J9	John Gilhen Jason Taylor	2
23 June 1997	NSM12611	North River, Colchester Co.	North River (NR)	45° 27' 15"N, 63° 12' 53"W	23D1,J11	John Gilhen Jason Taylor	5
28 June 1997	NSM12614	North River, Colchester Co.	North River (NR)	45° 27' 15"N, 63° 12' 53"W	23D1,J11	John Gilhen	13
28 June 1997	NSM12615	North River at North River, Colchester Co.	North River (NR)	45° 25' 30"N, 63° 15' 15"W	23D1,P16	John Gilhen Karen Gilhen	70
28 June 1997	NSM12616	Salmon River at Salmon River Road, Colchester Co.	Salmon River (SR)	45° 22' 15"N, 63° 13' 30"W	23D2,H12	John Gilhen Karen Gilhen	18
27 July 1997	NSM12618	Great Village River, Colchester Co.	Great Village River (GVR)	45° 24' 55"N, 63° 35' 53"W	23A2,J7	John Gilhen	24
27 July 1997	NSM12619	Portapique River, Colchester Co.	Portapique River (PR)	45° 24' 23"N, 63° 42' 46"W	19E2,K8	John Gilhen	11
2 August 1997	NSM12620	East Branch Moose River, Cumberland Co.	Moose River (MR)	45° 25' 13"N, 64° 11' 37"W	19A2,M7	John Gilhen	13

continued

APPENDIX 2. *Continued*

Date Collected	Catalogue Number	Locality (NS)	Watershed	Lat/Long	NS Map Reference	Collected by	Number of Specimens
23 August 1997	NSM12628	Portapique River above Montrose, Colchester Co.	Portapique River (PR)	45° 25' 43"N, 63° 42' 15"W	19E1,K16	John Gilhen	7
23 August 1997	NSM12629	Great Village River, near Londondary, Colchester Co.	Great Village River (GVR)	45° 28' 30"N, 63° 36' 45"W	23A1,H11	John Gilhen	20
23 August 1997	NSM12630	Rockland Brook at Londondary, Colchester Co.	Great Village River (GVR)	45° 28' 35"N, 63° 35' 35"W	23A1,H11	John Gilhen	19
31 August 1997	NSM12631	Steele Run, Colchester Co.	Salmon River (SR)	45° 28' 38"N, 63° 03' 52"W	23E1,K11	John MacMillan	5
10 September 1997	NSM12632	Salmon River at Route 104, Colchester Co.	Salmon River (SR)	45° 27' 45"N, 63° 04' 30"W	23E1,K12	John Gilhen	10
5 May 1998	NSM12633	Moose River, Cumberland Co.	Moose River (MR)	45° 25' 10"N, 64° 11' 35"W	19A2,M7	John Gilhen Andrew Hebda	10
7 May 1998	NSM12635	Christie Brook, Colchester Co.	Salmon River (SR)	45° 22' 51"N, 63° 11' 45"W	23D2,K11	John Gilhen	21
9 May 1998	NSM12636	Leppard Brook, Colchester Co.	Salmon River (SR)	45° 21' 26"N, 63° 16' 30"W	23C2,O14	John Gilhen	7
9 May 1998	NSM12637	Christie Brook, Colchester Co.	Salmon River (SR)	45° 22' 51"N, 63° 11' 45"W	23D2,K11	John Gilhen	44
9 May 1998	NSM12638	Matheson Brook, Colchester Co.	Salmon River (SR)	45° 30' 23"N, 63° 05' 58"W	23E1,H7	John Gilhen	9
15 May 1998	NSM12639	Debert River at East Folly Mountain Road, Colchester Co.	Debert River (DR)	45° 28' 55"N, 63° 26' 30"W	23B1,L10	John Gilhen	2
15 May 1998	NSM12643	Folly River, Colchester Co.	Folly River (FR)	45° 23' 51"N, 63° 31' 47"W	23A2,O9	John Gilhen	16
22 May 1998	NSM12647	Christie Brook, Colchester Co.	Salmon River (SR)	45° 22' 51"N, 63° 11' 45"W	23D2,K11	John Gilhen	26
24 May 1998	NSM12648	Salmon River at road to Riversdale, Colchester Co.	Salmon River (SR)	45° 25' 45"N, 63° 04' 53"W	23E1,J16	John Gilhen	16
24 May 1998	NSM12649	Christie Brook, Colchester Co.	Salmon River (SR)	45° 22' 51"N, 63° 11' 45"W	23D2,K11	John Gilhen	9
30 May 1998	NSM12651	Little Forks River, Cumberland Co.	Maccan River (MAR)	45° 42' 10"N, 64° 08' 30"W	18B3,G15	John Gilhen	7

continued

APPENDIX 2. *Continued*

Date Collected	Catalogue Number	Locality (NS)	Watershed	Lat/Long	NS Map Reference	Collected by	Number of Specimens
30 May 1998	NSM12652	Maccan River at Southampton, Cumberland Co.	Maccan River (MAR)	45° 35' 37"N, 64° 15' 00"W	18A5,H7	John Gilhen	20
30 May 1998	NSM12655	Folly River at Route 104, Colchester Co.	Folly River (FR)	45° 23' 52"N, 63° 31' 45"W	23A2,O9	John Gilhen	9
30 May 1998	NSM12656	Debert River at Route 104, Colchester Co.	Debert River (DR)	45° 23' 45"N, 63° 30' 40"W	23A2,P10	John Gilhen	9
31 May 1998	NSM12657	West Brook, Cumberland Co.	Maccan River (MAR)	45° 34' 32"N, 64° 16' 15"W	18A5,F9	John Gilhen	11
13 June 1998	NSM12658	Black River at Riversdale, Colchester Co.	Salmon River (SR)	45° 25' 23"N, 63° 02' 55"W	23E2,M7	John Gilhen	12
2 July 1998	NSM12659	East Branch Southampton River, Cumberland Co.	Maccan River (MAR)	45° 35' 35"N, 64° 14' 56"W	18A5,H7	John Gilhen	4
13 August 1998	NSM12662	Christie Brook, Colchester Co.	Salmon River (SR)	45° 22' 51"N, 63° 11' 45"W	23D2,K11	John Gilhen	25
11 September 1998	NSM12663	Atkinson Brook, Cumberland Co.	River Hebert (RH)	45° 35' 45"N, 64° 24' 16"W	12E5,F7	John Gilhen	5
11 September 1998	NSM12664	River Hebert, Cumberland Co.	River Hebert (RH)	45° 36' 00"N, 64° 21' 05"W	12E4,K16	John Gilhen	5
12 November 1999	NSM85144	Greenfield Brook, Colchester Co.	Salmon River (SR)	45° 22' 05"N, 63° 06' 30"W	23E2,H15	Karen March	1
12 November 1999	NSM85145	Unnamed brook, Colchester Co.	Salmon River (SR)	45° 21' 53"N, 63° 15' 35"W	23C2,O13	Karen March	1

Bill Dore's Notes on the Kaladar Cactus (*Opuntia fragilis*)

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The late botanist William G. Dore habitually left copious notes with his herbarium specimens and kept files on interesting plants while at the Biosystematics Research Institute of the Canada Department of Agriculture in Ottawa, Ontario. Analysis of his specimens, notes and letters regarding an isolated colony of Brittle Prickly-pear Cactus (*Opuntia fragilis*) from Kaladar in eastern Ontario led to the unfolding of a botanical story of discovery and rediscovery. This colony was first discovered in 1934, the location apparently lost and subsequently rediscovered in 1947, more or less neglected, and then brought to the attention of a wider circle of botanists in the mid 1960s. Attempts to determine its taxonomic identification were thwarted by the infrequency of flowering until the early 1960s.

Key Words: William (Bill) G. Dore, Brittle Prickly-pear Cactus, *Opuntia fragilis*, discovery, determination, Kaladar, Ontario.

The eminent Canadian plant biologist and naturalist, William (Bill) G. Dore, left a legacy of botanical contributions when he died in 1996 (*see* Darbyshire 1998). These included excellent herbarium specimens in the Vascular Plant Herbarium of the Biosystematics Research Institute in Ottawa (now called the Eastern Cereal and Oilseed Research Centre, Agriculture and Agrifood Canada), to which supplemental information had been routinely appended (Darbyshire 1998). Bill Dore's specimens with their added notations and his cactus files showed a particular personal interest in a remarkable disjunct colony of *Opuntia fragilis* (Brittle Prickly-pear Cactus) from a single rock outcrop, near Kaladar in eastern Ontario (*see* Beschel 1967b; Staniforth and Frego 2000). This population is approximately 1000 km east of the nearest part of the main range for the species, in Wisconsin (*see* distribution map in Staniforth and Frego 2000). The objective of this note is to explore Bill Dore's specimens, annotations, notes and letters on the Kaladar cactus in order to document the events surrounding its discovery, determination and possible origin.

Materials and Methods

Relevent specimens, letters, annotations and notes were obtained from two sources. Firstly, Dore generously provided a copy of his entire *Opuntia* file to K.A.F. in 1980 (Frego 1980*, Dore 1980*). Secondly in April 2000, W.J.C. retrieved materials from the herbarium file for *Opuntia fragilis* housed in the Vascular Plant Herbarium of the Eastern Cereal and Oilseed Research Centre, Agriculture and Agrifood Canada. Together, these consisted of four herbarium specimens (*MacClement 6372, Dore and Senn 47-671, Moore 2765, Dore 22811*) with their annotation labels, 11 letters sent by or to Bill Dore, two pages of typed and four pages of hand written notes. The specimens and written material spanned the years from 1934 to 1980. Collectively these items captured the history of the discovery of the colony, the determination of identification for the cactus species, and some of the thought that went into the consideration of the colony's origin. We organised photocopies of the items into a chronological sequence (*see* Documents and Specimens Cited section) and their information contents were linked to present a history of discovery for *Opuntia fragilis* in eastern Ontario.

Results and Discussion

Discovery

Local people knew of the cactus colony long before it was "discovered" by a professional botanist in 1934. According to Mary I. Moore of Deep River, Ontario (Moore 1965*, 1967*, 1973*), three generations of the Smedley family had known of its location since about 1905. On the other hand, and to the frustration of the researchers, directions to the site by locals usually turned out to be erroneus. For instance, David Brydson, the owner of a local hotel, was notably inaccurate regarding the colony's whereabouts and its flowering characteristics, even though he had transplants growing in his own garden (Dore 1947*, 1949b*,1967c*).

W. T. MacClement (Professor of Botany, Queen's University, Kingston 1906-1936; *see* Smallman et al. 1991) appears to have made the first botanical collection of the cactus in May 1934 (MacClement 1934*).

We have no information as to how MacClement became aware of the site. Claude Garton (Lakehead University) later recalled (Dore 1978*) that the event had been a Sunday field trip to the site for botany students from Queen's University. A pressed specimen was sent to Merritt Fernald at the Gray Herbarium, Harvard University, for identification. However, there is no record of any determination having been made by Fernald and it appears that the specimen was overlooked for the next 31 years. The MacClement field trip also resulted in living plants being cultured in the greenhouse at Queen's by MacClement and his successors R. O. Earl (Dore 1967c*) and A. Crowder (Crowder 1973*).

Apparently, unaware of the MacClement "discovery" and the existence of the Harvard specimen (Dore 1967a*), Dore and others continued trying to verify rumours that a wild cactus existed somewhere in southeastern Ontario (Dore 1947*). Herbert Groh (Department of Agriculture, Ottawa) and Dore, acting on erroneus directions by local people, searched the Kaladar area without success but may even have been as close as the opposite side of the road in 1942 (Dore 1947*). Jack Gillett eventually relocated the colony on 30 July 1947 (Dore 1947*) and informed Dore, who travelled to the site with Harold Senn during the following week and procured a specimen for the Biosystematics Research Institute (Dore and Senn 1947*). The site was next visited by Dore, Senn and Clarence Frankton (Department of Agriculture, Ottawa) on 17th August 1949 (Dore 1949b*).

The next recorded visit did not occur until 3rd May 1965 (Moore 1965*), when Mary Moore (Deep River, Ontario) collected a specimen. Coincidentally, in June 1965, Bernard Boivin of Agriculture Canada unexpectedly encountered the forgotten MacClement specimen while visiting the Gray Herbarium. He reported its existence to his colleague Bill Dore (Dore 1967a*). It appears that no one in Ottawa was aware of the existence of this early specimen, and its discovery must have been quite an exciting event. A photograph of the original Gray Herbarium specimen was soon accessioned into the Herbarium of the Biosystematics Research Institute (MacClement 1934*). This was likely to have been the stimulus behind renewed investigations into the cactus by Dore and others in the mid- and late 1960s (Dore 1966*).

On 30th May 1967, Dore, Roland Beschel (Queen's University, Kingston), Paul Maycock (Erindale College), Gunnar Wassen (National Herbarium, Ottawa) and probably others visited the site. Wassen took black-and-white photographs of the plants (Dore 1967b*) and the site (Figure 1).

FIGURE 1. A photograph of the Brittle Prickly-pear Cactus (*Opuntia fragilis*) site, near Kaladar, southeast Ontario taken by Gunnar Wassen during a field trip with W. Dore, R. Beschel, P. Maycock (and possibly others) in May 1967.

FIGURE 2. A photograph of cactus cladodes "attached to Paul Maycock's big boot" (Dore 1967b) taken by G. Wassen in May 1967 at the Kaladar site.

Later that same year, Beschel led the Canadian Botanical Association on one of its first field trips which included a visit to the cactus colony (Beschel 1967a*). In June 1967, Beschel published a description of the site and the cacti in the Quarterly Bulletin of the Kingston Naturalists (Beschel 1967). At the same time and perhaps unwittingly, Dore drafted a longer article and sent it to Beschel for review and possible co-authorship (Dore 1967c*). In his covering letter to Beschel, Dore recommended that an appropriate place for publication would be the *Ontario Naturalist*. This article was never published even though Beschel revisited the site in July 1967 to take more photographs and gather more descriptive information about the cacti and other plants at the site (Beschel 1967b*).

Determination

The identity of the Kaladar cactus appears to have been nearly as elusive as its discovery. This was likely attributable to its similarity to certain other species in the genus (such as *O. polyacantha*) and to the rarity of flowers in Kaladar plants. The MacClement specimen was originally determined as "*Opuntia*" in 1934 (MacClement 1934*). R. O. Earl of Queen's University sent the MacClement specimens to M. O. Malte (Chief Botanist, National Museum) for identification but the lack of flowers led to inconclusive results (Dore 1947*). During 1949, Dore wrote to cactus experts Elzada Clover (University of Michigan) and H. A. Shetrone (Ohio State Museum) to seek help with the identification process (Dore 1949a*, 1949c*; Meyer 1949*) but there is no documentation of any reply. In the 1950s and early 1960s, most specimens (Dore and Senn 1947*; Moore 1965*; Dore 1966*) were being labelled as "Opuntia (?fragilis) Haw." but the origin of this tentative determination is unknown as is the basis on which it was made. There seems to have been no uncertainty in the determination by the time that Beschel undertook his studies on the cactus in 1967 (Beschel 1967a*, 1967b*). All specimens that we examined had been confirmed with annotations as *Opuntia fragilis* (Nutt.) Haw. by Lyman Benson (Pomona College, Claremont, California) in April 1972 and by Bruce Parfitt (Arizona State University) in 1991.

Colony origins

Alternate hypotheses to explain the origin of this anomalous disjunct distribution have been developed by Beschel (1967b*), Dore (1967c*) and Staniforth and Frego (2000). The two hypotheses are: (1) human introduction at an unknown date, or (2) as a relict of a wider distribution during hypsithermal period, 8000-4000 years before present. Dore's documents in the late 1940s indicate that these hypotheses were already being formulated at that time; i.e., "Mr. Gillett is of the opinion that the cactus is introduced or escaped" (Dore 1947). At the Annual General Meeting of the Canadian Botanical Association (Vancouver, June 1980), Dore hypothesised that both *Lithospermum canescens* and *Opuntia fragilis* may have been purposely spread by aboriginal people because the former possesses a red dye whereas mucillage from stems of the cactus can act as a mordant for the dye. We were recently enlightened by Daniel Brunton of Ottawa (Brunton 2000*) of another of Dore's explanations: "The colonization road upon which the nearby highway was later constructed was put in when a 19th century gold rush occurred in the area just to the north (of Kaladar); this was, I believe, about the time that the California gold rush was winding down. It's not hard to imagine some western gold seeker unknowingly brought a pad along on his gear, only to have it fall or be broken off at the Kaladar site". In support of the relict hypothesis, Dore wrote that he, Clarence Frankton and Harold Senn had observed other associated species at Kaladar "which may indicate affinity with a more southern or western climatic area" (Dore 1949b*) suggesting that the cactus was part of a relict hypsithermal community. This second hypothesis is now thought to be less likely (Staniforth and Frego 2000), largely because closely associated species do not have western or southern affiliations as was originally proposed. However, some southern species reach their northern limits in the general region (Brownell et al. 1996).

Conclusions

The isolation of disjunct plant populations intrigued and challenged Bill Dore's imagination for explanations. The Brittle Prickly-pear Cactus

growing near Kaladar, in eastern Ontario: a population located more than 1000 km from the main range of the species is an excellent example of this. We can imagine that rumours of its existence amongst local people reached Bill Dore and other Ottawa (and Kingston) botanists, in the 1940s. The task of finding the colony (and perhaps the challenge of who would be the first to detect it!) resulted in several botanising expeditions, but it was Jack Gillett who eventually discovered the site. The hunt was then replaced by the challenge of formulating an acceptable, logical, ecological or historical explanation of its origins. Dore excelled at this. Darbyshire (1998) noted that "Bill is well known for his hypotheses of aboriginal and early European influences" when attempting to explain the unusual distributions of plants, but cautions, "Although many people have been quick to reject these explanations of present-day plant distributions, few have offered contesting hypotheses to explain 'how' and 'why'". Dore's letters, specimens and copious annotations allowed us to follow the events which led to the discovery, species determination and hypotheses of origin for this unusual population and in so doing, they have contributed an interesting aspect to the history of discovery of the Canadian flora (*see* Pringle 1995).

Acknowledgments

The authors are grateful to Mrs. R. E. Beschel of Kingston for providing us with the photographs that had been taken during the 1967 field trip to the cactus site near Kaladar, Ontario. These photographs and also the documents mentioned below are filed with R.J.S. at the University of Winnipeg.

Documents and Specimens Cited

(marked * in text), in chronological sequence

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Dore, W. G. 1947. Two typed pages, signed and dated ("Fall 1947") and identified as "Re. 47.671". Attached to *Collection number: Dore & Senn 47–671* (DAO 82191).

Dore, W. G. 1949a. Letter to Dr. Bernard S. Meyer, Ohio State Unversity. Dated 4 April 1949.

Meyer, B. S. 1949. Letter to W. G. Dore. Dated 14 April 1949.

Dore, W. G. 1949b. Two hand-written pages, signed and dated ("Dec. 5, 1949"). Attached to *Collection number: Dore & Senn 47-671* (DAO 82191).

Dore, W. G. 1949c. Letter to Dr. Elzada Clover, University of Michigan. Dated 6 December 1949.

Moore, M. I. 1965. Herbarium specimen of *Opuntia fragilis. Collection number: Moore 2765.* (DAO 82194)

Dore, W. G. 1966. Herbarium specimen of *Opuntia fragilis. Collection number: Dore 22811.* (DAO 82193)

Dore, W. G. 1967a. Handwritten note dated (18 May 1967) and signed. Attached to *MacClement, W. T. 6372* (DAO 269655).

Beschel, R. E. 1967a. Field trip 1 to the Kingston region led by R. E. Beschel, Queen's University. Annual meeting of the Canadian Botanical Association. Ottawa. 30 May 1967. Mimeographed sheets.

Dore, W. G. 1967b. Letter to Dr. Gunnar Wassen. Dated 15 June 1967.

Dore, W. G. 1967c. Letter to Roland E. Beschel. Dated 18 June 1967. Attached to a rough draft of a 12 page manuscript "Rare Cactus in Ontario Wilderness by William G. Dore and Roland E. Beschel".

Beschel, R. E. 1967b. Letter to W. G. Dore. Dated 27 July 1967.

Moore, M. I. 1967. Letter to W. G. Dore. Dated 17 August 1967.

Moore, M. I. 1973. Letter to W. G. Dore. Dated 9 April 1973.

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Dore, W. G. undated (but post-1978). Hand-written note regarding visit to cactus area by Claud Garton and Prof. MacClement in 1933 or 1934.

Dore, W. G. 1980. Letter to Katherine Frego. Dated 2 July 1980.

Frego, K. A. 1980. A copy of Dore's "cactus file" given to K. A. Frego in 1980.

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Amphibian and Reptile Diversity along the St. Lawrence River

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Jobin, Benoît, David Rodrigue, and Jean-Luc DesGranges. 2002. Amphibian and reptile diversity along the St. Lawrence River. Canadian Field-Naturalist 116(4): 551–558.

The Biodiversity Portrait of the St. Lawrence project was initiated to gain insight into the natural and anthropogenic factors that affect biodiversity and to have a better understanding of species distribution along the St. Lawrence River. This paper presents a regional analysis of the diversity of herpetofauna living along the Québec portion of the St. Lawrence River and identifies areas to be protected for the maintenance of amphibian and reptile populations in southern Québec. Data collected since the end of the 19th century were compiled in geographic units (natural provinces) and in a systematic grid of 100-km^2 quadrats. The herpetofauna of the St. Lawrence River is composed of 33 species: 18 amphibians and 15 reptiles. The most commonly recorded amphibians were the American Toad (*Bufo americanus*), Spring Peeper (*Pseudacris crucifer*), Northern Leopard Frog (*Rana pipiens*) and Wood Frog (*Rana sylvatica*), and the most abundant reptiles were the Common Garter Snake (*Thamnophis sirtalis*), Painted Turtle (*Chrysemys picta*) and Common Snapping Turtle (*Chelydra serpentina*). Species richness was greater in the southern portion of the St. Lawrence in the Montréal region where most records of species with high-priority conservation status in Québec were also concentrated, making this a high-priority region for conserving the biodiversity of Québec's herpetofauna.

Key Words: amphibians, reptiles, herpetofauna, St. Lawrence, biodiversity, conservation, species richness, distribution.

La production du Portrait de la biodiversité du Saint-Laurent visait à mieux comprendre les facteurs naturels et anthropiques qui agissent sur la biodiversité et à préciser nos connaissances sur la distribution des espèces fauniques et floristiques vivant le long du fleuve Saint-Laurent. Nous présentons une analyse régionale de la diversité de l'herpétofaune retrouvée dans la portion québécoise du Saint-Laurent et nous identifions des secteurs où des actions de conservation devraient être entreprises afin de protéger les populations d'amphibiens et de reptiles du sud du Québec. Les observations compilées depuis la fin du 19ème siècle ont été intégrées dans un cadre écologique (provinces naturelles) et dans une grille arbitraire formée de parcelles de 100 km^2. L'herpétofaune du Saint-Laurent est composée de 33 espèces soit 18 amphibiens et 15 reptiles. Les amphibiens les plus fréquemment observés sont le Crapaud d'Amérique (*Bufo americanus*), la Rainette crucifère (*Pseudacris crucifer*), la Grenouille léopard (*Rana pipiens*) et la Grenouille des bois (*Rana sylvatica*), tandis que les reptiles les plus communs sont la Couleuvre rayée (*Thamnophis sirtalis*), la Tortue peinte (*Chrysemys picta*) et la Chélydre serpentine (*Chelydra serpentina*). La richesse spécifique était plus élevée dans la région de Montréal, là où la majorité des observations des espèces ayant un statut de conservation élevé ont également été effectuées. Cette région présente donc un intérêt majeur pour la conservation de la biodiversité de l'herpétofaune québécoise.

Mots-clés : amphibiens, reptiles, herpétofaune, Saint-Laurent, biodiversité, conservation, richesse spécifique, distribution.

The St. Lawrence Vision 2000 Action Plan (SLV 2000), a federal-provincial program developed to study and protect the St. Lawrence River ecosystems, was implemented to gain insight into natural and anthropogenic factors that affect biodiversity and to have a better understanding of species distribution along the St. Lawrence River, in order to direct conservation efforts in areas where species at risk are concentrated. Because the different sources of information on the physical and biotic characteristics of the St. Lawrence were scattered in the scientific literature, in unpublished reports, and in non-centralized databases, the Biodiversity Portrait of the St. Lawrence project was initiated in 1995 and aimed at gathering and synthesising much of the data collected over the last 30 or so years on species distribution of the major taxonomic groups, from plants to mammals, living in or along the St. Lawrence River (DesGranges and Ducruc 2000*).

Amphibian and reptile distribution was part of this portrait, being of particular interest considering the declining population trends of several species, especially in anurans (frogs and toads), recently observed in Canada (Bishop and Pettit 1992; Green 1997) and worldwide (Blaustein and Wake 1990; Phillips 1990). Because many amphibian and reptile species rely on wetlands or riparian habitats to complete their life cycle, they are prone to be greatly affected by wetland drainage and habitat losses. It is estimated that more than 50% the St. Lawrence banks between Cornwall and Québec City have lost their natural integrity, and that shoreline modification has been almost three times greater in this freshwater section, where human densities are the highest in the

*See Documents Cited section.

province, than downstream in the estuary and gulf sections of the river (Picard et al. 1997*). Because herpetofaunal populations are sensitive to human disturbance (Green 1997; White et al. 1997), monitoring species diversity is essential to trigger early warnings permitting effective measures to be adopted to deal with threats to ecosystem integrity. This paper presents a regional analysis of the diversity of herpetofauna living along the St. Lawrence River and identifies areas to be protected for the maintenance of amphibian and reptile populations in southern Québec.

Study Area and Methods

The St. Lawrence Valley Natural History Society, in collaboration with the Société de la faune et des parcs du Québec (FAPAQ), manages a databank containing observations of amphibians and reptiles in Québec gathered by amateur volunteers and professionals since the end of the 19th century, including historic museum records. Analysis of the data gathered prior to 1993 led to the publication of the Atlas of Amphibians and Reptiles of Quebec (Bider and Matte 1996). The data used in our study were extracted from this databank updated in 1996. It contains 4010 records obtained along the St. Lawrence River system. More than 55% of these observations were made during the period 1993–1996; i.e.; additional data gathered since the latest edition of the Atlas, and 85% of all observations were made between 1988 and 1996. Common and scientific names of amphibian and reptile species follow Alvo and Oldham (2000).

For this project, the study area encompasses the entire St. Lawrence River banks located in Québec from the Québec-Ontario border near Cornwall (45° 01′ N, 74° 43′ W), Ontario, to its northeasternmost area of Blanc-Sablon (51° 25′ N, 57° 08′ W) near the Labrador border. All data collected along the river and within 10 km of its riverbanks, including the Montréal archipelago, the Saguenay River, and the Gulf of St. Lawrence (Baie-des-Chaleurs, Magdalen Islands) were included in the analyses. Ducruc et al. (1995) presented an ecological reference framework developed at the scale of the entire province which is divided into terrestrial units based on stable parameters representing the physical environment, and characterized with several ecological variables. We present the portrait of the diversity of amphibians and reptiles at the level of the six natural provinces found along the St. Lawrence River, ranging from the deciduous forests of the St. Lawrence Lowlands to the tundra vegetation of the Lower North Shore (Figure 1), where the geographic coordinates of each record were used to assign them to a natural province.

In addition to these natural provinces, records of amphibians and reptiles were also superimposed on an arbitrary division consisting of a systematic grid composed of 100-km^2 quadrats (10 × 10 km). A mathematical model was used to divide the study area into 751 adjoining quadrats, starting at the southernmost point in Québec (the Québec-Ontario border). All quadrats located less than 10 km from the banks of the St. Lawrence River were included in the study area.

Only the presence of a species in a geographic unit, regardless of the number of records and of the species abundance, was used in species richness calculations (total number of species in each geographic unit). We acknowledge that species abundance would have provided a more accurate portrait of the regional distribution of amphibians and reptiles but this option was discarded because abundance values were missing from nearly half (44%) of the 4010 records.

Global (GRANKs) and provincial (SRANKs) conservation priority ranking of species, as provided by NatureServe (1999*) and the Centre de données sur le patrimoine naturel du Québec (CDPNQ 1999*), are listed in Alvo and Oldham (2000) and were used to identify species at risk. The Québec priority ranking of S1 was given to species most at risk, compared with S5 for abundant species. A composite prioritization index for the 100-km^2 quadrats was calculated by attributing 5, 3 or 1 point to species with Québec priority ratings of S1, S2 and S3 respectively, corresponding to the species requiring the most attention from a biodiversity conservation standpoint. The importance of each quadrat in terms of the priority species it contains was assessed with a composite index of prioritization comparing the total points calculated per quadrat with the highest possible total of 31 for a quadrat which would contain all priority species located along the St. Lawrence (S1 = 3 species, S2 = 3 species, S3 = 7 species):

$$\text{Composite index} = \frac{(\text{n species S1} \times 5) + (\text{n species S2} \times 3) + (\text{n species S3} \times 1)}{31 \text{ (maximal possible index value)}}$$

Results

Herpetofauna richness

The herpetofauna found along the St. Lawrence River is composed of 33 species: 18 amphibians and 15 reptiles. The most commonly observed amphibians were the American Toad (*Bufo americanus*), Spring Peeper (*Pseudacris crucifer*), Northern Leopard Frog (*Rana pipiens*) and Wood Frog (*Rana sylvatica*), while the most abundant reptiles were the Common Garter Snake (*Thamnophis sirtalis*), Painted Turtle (*Chrysemys picta*) and Common Snapping Turtle (*Chelydra serpentina*) (Table 1). Species richness was significantly greater in the natural provinces of southern Québec than in the more easterly ones (Table 1; Figure 1). There were over 32

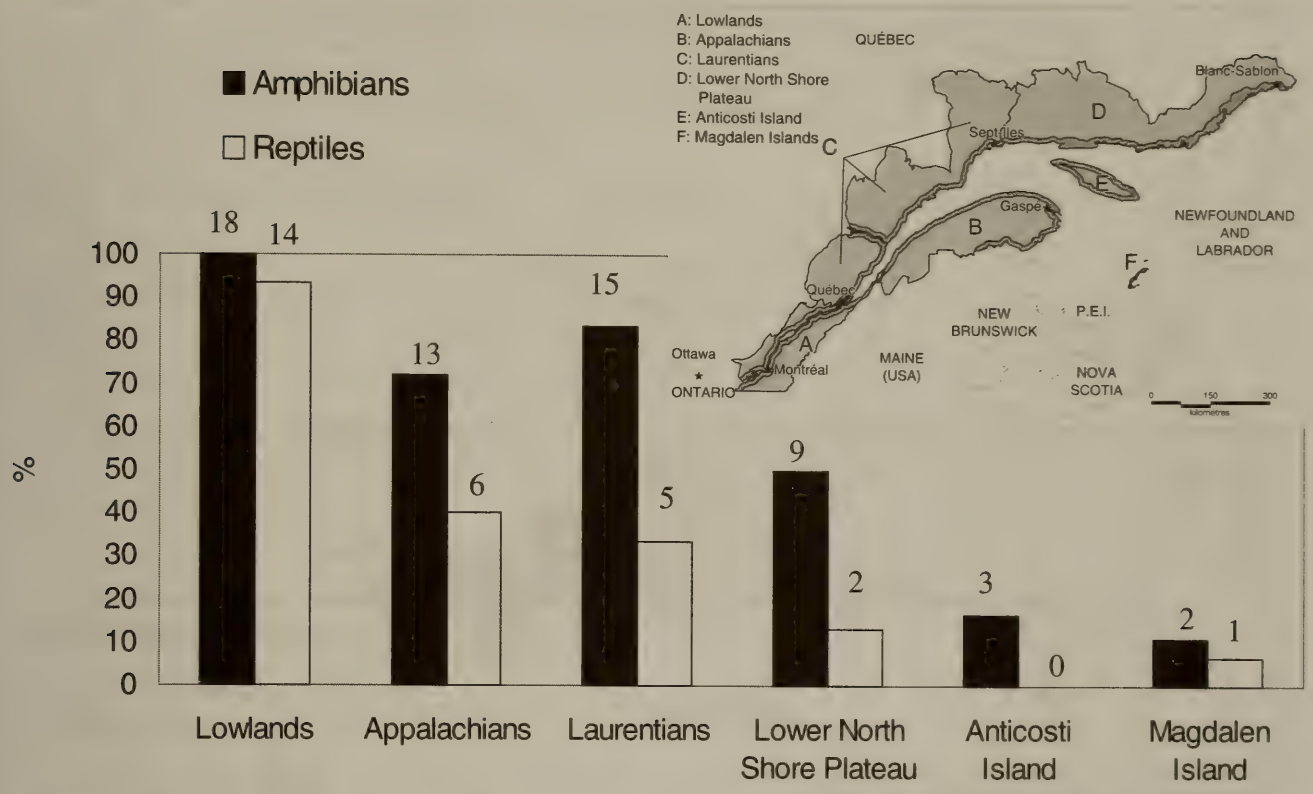

FIGURE 1. Number and percentage of amphibian and reptile species observed in the six natural provinces along the St. Lawrence River in Québec. Inset shows the localisation of natural provinces and their 10km-wide zone along the St.Lawrence River where amphibian and reptile records were compiled.

species in the St. Lawrence Lowlands versus fewer than ten species on the Lower North Shore Plateau, Anticosti Island and the Magdalen Islands. While the number of reptile species decreases as one moves downstream along the St. Lawrence River, amphibian diversity remains fairly steady throughout the freshwater section and estuary and then rapidly declines in the Gulf. Although found elsewhere in Québec, three species (Spring Salamander [*Gyrinophilus porphyriticus*], Mountain Dusky Salamander [*Desmognathus ocrophaeus*], Common Musk Turtle [*Sternotherus odoratus*]) and one subspecies (Boreal Chorus Frog [*Pseudacris triseriata maculata*] were not recorded along the St. Lawrence River.

The richest sites for both amphibians and reptiles are located in southwestern Québec around the Lac des Deux-Montagnes, Lac Saint-Louis and Lac Saint-François. The richest quadrat in the river system was the Île Perrot quadrat where 16 species of amphibians and 13 species of reptiles were recorded, followed by the quadrats along the Lac des Deux-Montagnes (16 amphibians, 9 reptiles) and in the Senneville–Sainte-Anne-de-Bellevue area (12 amphibians, 8 reptiles). Quadrats in the Valleyfield (12 amphibians, 7 reptiles) and Saint-Clet regions (13 amphibians, 5 reptiles) also showed high species richness. The Baie de Beauport quadrat in the Québec City region is noteworthy among the quadrats east of Montréal for its high number of species (12 amphibians, 6 reptiles). The Magdalen Islands had only one record for a reptile (one Leatherback [*Dermochelys coriacea*]), while Anticosti Island had none. Maps showing all of the 100-km^2 quadrats where each species was observed along the St. Lawrence River are available on The Biodiversity Portrait of the St. Lawrence web site (DesGranges and Ducruc 2000*).

Species of concern

Four amphibian and nine reptile species observed along the St. Lawrence River have a high-priority conservation status in Québec (Table 1) but their populations would not be threatened globally (global ranks = G4 or G5). In addition, the Leatherback has a high-priority status globally (G3) but was not considered threatened in Québec (SZN) due to its sporadic occurence along its coasts. Most records for species of concern came from the Montréal region, where 11 out of 13 listed species were observed around the Lac des Deux-Montagnes and Lac Saint-Louis (Figure 2). The quadrats with the highest prioritization index (Table 2) were also those with the highest species richness (Île Perrot, Pointe-Claire, Lac des Deux-Montagnes, Senneville). Several neighbouring quadrats (Roxboro, Laval, Laval-north, Mont-Royal) also supported many species of concern. Some observations of species of concern were made east of Lac Saint-Pierre such as the Wood

TABLE 1. Number of records of each amphibian and reptile species in the six natural provinces along the St. Lawrence River.[1]

Species	Scientific name	Priority rank[2]		Natural province							
		Québec	Global	Lowlands	Laurentians	Appalachians	Lower North Shore Plateau	Anticosti Island	Magdalen Islands	Total	%
Amphibians											
American Toad	*Bufo americanus*	S5	G5	356	63	95	12	0	0	526	13.1
Spring Peeper	*Pseudacris crucifer*	S5	G5	372	52	42	4	1	0	471	11.7
Northern Leopard Frog	*Rana pipiens*	S5	G5	400	8	18	4	6	0	436	10.9
Wood Frog	*Rana sylvatica*	S5	G5	214	52	102	4	0	0	372	9.3
Green Frog	*Rana clamitans*	S5	G5	287	16	13	2	0	2	320	8.0
Bullfrog	*Rana catesbeiana*	S4	G5	153	2	0	0	0	2	157	3.9
Redback Salamander	*Plethodon cinereus*	S5	G5	106	9	38	1	0	0	154	3.8
Gray Treefrog	*Hyla versicolor*	S4	G5	110	2	0	0	0	0	112	2.8
Eastern Newt	*Notophthalmus viridescens*	S5	G5	62	16	25	0	0	0	103	2.6
Mink Frog	*Rana septentrionalis*	S5	G5	41	23	28	1	10	0	103	2.6
Blue-spotted Salamander	*Ambystoma laterale*	S5	G5	65	6	12	1	0	0	84	2.1
Western Chorus Frog	*Pseudacris triseriata*	S3	G5	66	0	0	0	0	0	66	1.6
Mudpuppy	*Necturus maculosus*	S4	G5	60	2	0	0	0	0	62	1.5
Spotted Salamander	Ambystoma maculatum	S5	G5	30	6	16	1	0	0	53	1.3
Northern Two-lined Salamander	Eurycea bislineata	S4	G5	25	14	5	0	0	0	44	1.1
Pickerel Frog	Rana palustris	S3	G5	23	1	3	0	0	0	27	0.7
Dusky Salamander	Desmognathus fuscus	S3	G5	17	0	1	0	0	0	18	0.4
Four-toed Salamander	Hemidactylium scutatum	S3	G5	7	0	0	0	0	0	7	0.2
Reptiles											
Common Garter Snake	*Thamnophis sirtalis*	S5	G5	174	35	51	2	0	0	262	6.5
Painted Turtle	*Chrysemys picta*	S4	G5	164	0	0	0	0	0	164	4.1
Common Snapping Turtle	*Chelydra serpentina*	S4	G5	120	1	3	0	0	0	124	3.1
Common Map Turtle	*Graptemys geographica*	S1	G5	116	0	0	0	0	0	116	2.9
Redbelly Snake	*Storeria occipitomaculata*	S5	G5	63	7	1	0	0	0	71	1.8
Brown Snake	*Storeria dekayi*	S2	G5	48	4	1	0	0	0	53	1.3
Northern Water Snake	*Nerodia sipedon*	S3	G5	28	0	0	0	0	0	28	0.7
Milk Snake	*Lampropeltis triangulum*	S3	G5	26	0	0	0	0	0	26	0.6
Wood Turtle	*Clemmys insculpta*[3]	S2	G4	11	2	2	0	0	0	15	0.4
Smooth Green Snake	*Liochlorophis vernalis*	S4	G5	13	0	0	0	0	0	13	0.3
Ringneck Snake	*Diadophis punctatus*	S3	G5	7	0	0	0	0	0	7	0.2
Spiny Softshell	*Apalone spinifera*	S1	G5	5	0	0	0	0	0	5	0.1
Blanding's Turtle	*Emydoidea blandingii*	S2	G4	5	0	0	0	0	0	5	0.1
Spotted Turtle	*Clemmys guttata*	S1	G5	2	0	1	0	0	0	3	0.1
Leatherback	*Dermochelys coriacea*	SZN	G3	0	0	0	2	0	1	3	0.1

[1]Data extracted from the St. Lawrence Valley Natural History Society databank, updated 1996
[2]Priority ranks according to Alvo and Oldham (2000)
[3]Editor's note: *Glyptemys insculpta* see Holman and Fritz 2001 Zoologische Abhandlungen, Museum Trerkundc Dresden 51 (20): 331–354.

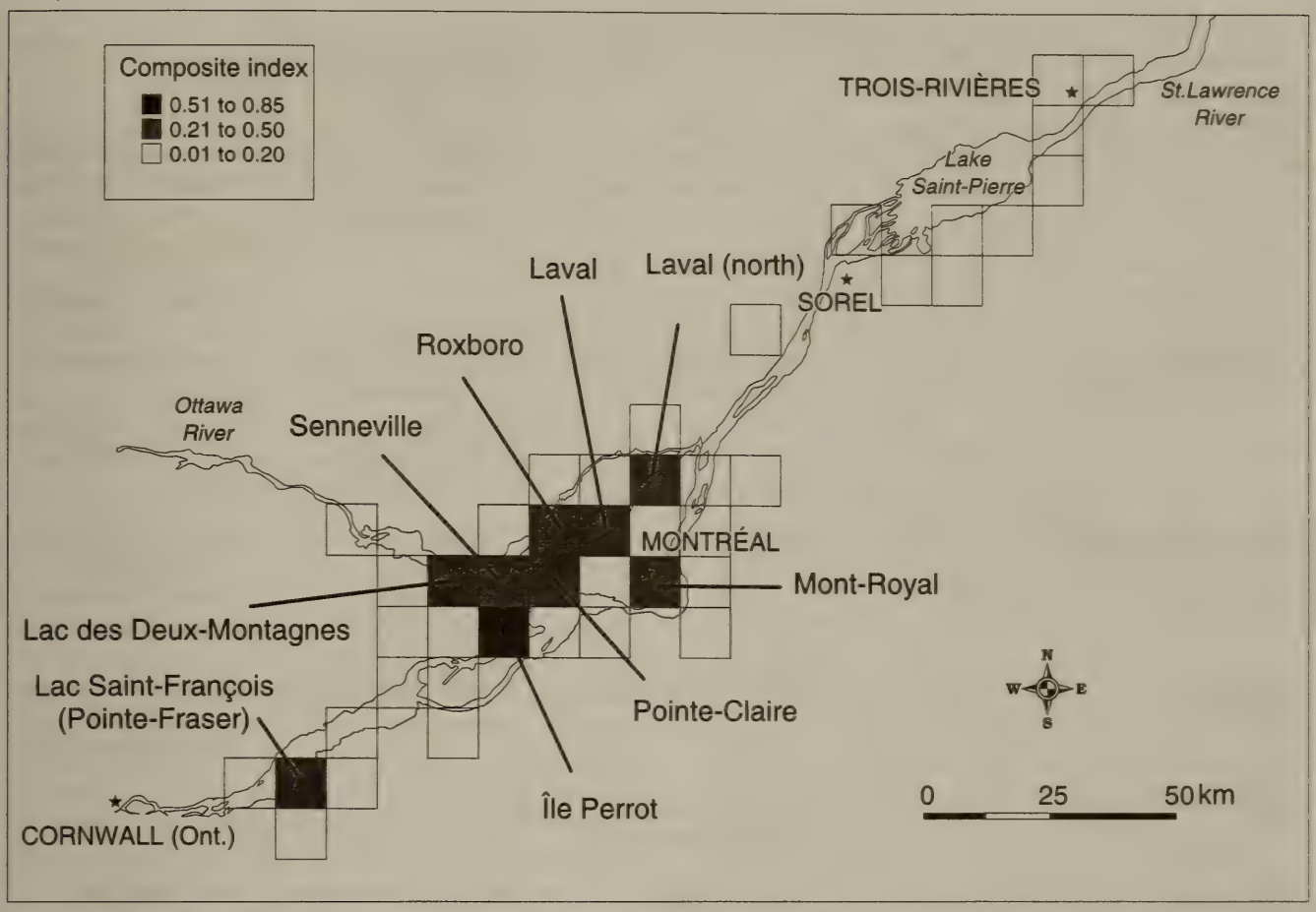

FIGURE 2. Value of the composite index of prioritization of herpetofauna for quadrats located in the Montréal region.

Turtle (*Clemmys insculpta*) and Brown Snake (*Storeria dekayi*) recorded in a few quadrats in the Québec City region and in the Laurentians and Appalachians provinces.

Discussion

Unlike previous publications on amphibian and reptile species distribution in eastern Canada where observation records were either mapped (Bleakney 1958; Logier and Toner 1961) or analysed to draw generalized distribution maps for each species (Cook 1984), we present a synthetic view of species richness for distinct geographic regions without specific emphasis on the actual distribution of each species. Our analysis clearly showed that amphibian and reptile species richness decreases as one moves downstream along the St. Lawrence River from the Montréal region to the Lower North Shore and the Gulf. Interestingly, the region of the Montréal archipelago showing the highest species richness corresponds well with Bleakney's (1958) herpetofaunal section 2 considered as the richest region in Québec which extends along the Outaouais River Valley, in the St.Lawrence Lowlands from the Québec-Ontario border down to Lake Saint-Pierre and extending over the Richelieu River drainage basin.

Several factors could contribute to a lower herpetofaunal species richness in the northeastern regions. Climatic conditions are harsher in the cold regions of the Lower North Shore Plateau and Anticosti Island which may limit species range (Bleakney 1958; Bider and Matte 1996; McKenney et al. 1998). Several species, including the Four-toed Salamander (*Hemidactylium scutatum*), Common Map Turtle (*Graptemys geographica*) and Spiny Softshell (*Apalone spinifera*), are at the northern limit of their range in southwestern Québec, their absence in colder regions thus contributing in a lower species richness beyond the St. Lawrence Lowlands. The lower diversity of habitats in the northeastern regions as compared to southern regions would also limit species distribution and species associated with specific habitat types should only be found in regions where this habitat occurs. For example, the Western Chorus Frog (*Pseudacris triseriata*) and the Smooth Green Snake (*Liochlorophis [Opheodrys] vernalis*) are generally associated with open fields (Cook 1984; Bider and Matte 1996) which are uncommon in the gulf regions thus increasing species richness in the south. Amphibian species observed on the Magdalen Islands and Anticosti Island were probably introduced, with the exception of the Mink Frog (*Rana septentrionalis*), which may be native to Anticosti Island (Bider and Matte 1996).

TABLE 2. Quadrats with the highest composite index of prioritization

Quadrat[1]	Composite Index	Species observed with conservation rank of S1	S2	S3
Île Perrot	0.81	Spiny Softshell Common Map Turtle	Blanding's Turtle Wood Turtle Brown Snake	Four-toed Salamander Western Chorus Frog Pickerel Frog Ringneck Snake Milk Snake Northern Water Snake
Pointe-Claire	0.39	Common Map Turtle	Blanding's Turtle Brown Snake	Milk Snake
Roxboro	0.39	Common Map Turtle	Wood Turtle Brown Snake	Milk Snake
Lac des Deux-Montagnes	0.39	Common Map Turtle	Brown Snake	Western Chorus Frog Pickerel Frog Ringneck Snake Northern Water Snake
Senneville	0.35	Common Map Turtle	Brown Snake	Western Chorus Frog Milk Snake Northern Water Snake
Laval	0.32	Spotted Turtle Common Map Turtle		
Laval (north)	0.29	Common Map Turtle	Blanding's Turtle	Milk Snake
Mont-Royal	0.29	Common Map Turtle	Brown Snake	Milk Snake
Lac Saint-François (Pointe-Fraser)	0.23	Common Map Turtle		Pickerel Frog Northern Water Snake

[1]See Figure 2 for quadrat location

Differential searching effort among regions would likely explain part of the variation of the observed species richness. Because Québec's human densities are at their highest in southern Québec, volunteers are also more numerous in this part of the province. This is reflected in the higher number of records coming from southern Québec. Because our analysis relied on records gathered over decades by volunteers and professionals under varied scenarios and using different methodologies, there were no consistent and rigorous procedures followed in data acquisition. It is therefore difficult to evaluate the relative importance of many factors (climate, habitat, searching effort) on the actual species distribution patterns. Our analysis, however, presents the best portrait of amphibian and reptile species distribution along the St. Lawrence based on the most up-to-date information available in Québec.

Initial distribution maps of Canadian amphibian and reptile species were published in Bleakney (1958), Logier and Toner (1961) and Cook (1984), and based largely on verifiable museum specimens. Comparison of these maps with records of species from the St. Lawrence River databanks based largely on reported observations reveals numerous additional localities gathered, especially since the Atlas of Amphibians and Reptiles in Québec project has been instigated, which have extended the presumed distribution of several species further north and east of their previously known limits (see Bider and Matte 1996). New locations mapped in Bider and Matte (1996) of the Four-toed Salamander and Spotted Turtle (*Clemmys guttata*) in the St. Lawrence Lowlands, the Gray Treefrog (*Hyla versicolor*) in Lake Saint-Pierre, the Common Snapping Turtle east of Québec City, and the Bullfrog (*Rana catesbeiana*), Spotted Salamander (*Ambystoma maculatum*) and Redbelly Snake (*Storeria occipitomaculata*) in Lake Saint-Jean are noteworthy. Most interestingly, additional locations of the Blanding's Turtle (*Emydoidea blandingii*) in the Montréal region and in the freshwater estuary section of the St. Lawrence west of Québec City have been reported to the data bank since the latest edition of the Atlas of Bider and Matte (1996). Caution must be exercised, however, in accepting observations

where no voucher specimens or photographs are available for verification. As well, all turtle records which "extend" a known range are initially most suspect because of the likelihood that they are based on escaped captives brought from natural populations elsewhere. Despite such reservations, deletion of suspect records would not significantly alter the general pattern described here.

Species of concern

Species of high-priority conservation status in Québec are generally designated as such because they are at the northern limit of their range, are uncommon, and are sensitive to habitat destruction (Beaulieu 1992; Bider and Matte 1996). However, with the exception of the Leatherback, global status populations are generally not of concern. Among the species with the highest conservation status in Québec (S1) which are observed along the St. Lawrence River, two (Spiny Softshell, Spotted Turtle) are included in a previous list of rare and endangered Canadian amphibian and reptile species (Cook 1970), but the Common Map Turtle is lacking from this list. Several other species of concern in Québec such as the Wood Turtle (S2), Brown Snake (S2), Four-toed Salamander (S3), Western Chorus Frog (S3), Pickerel Frog (*Rana palustris*; S3), Northern Water Snake (*Nerodia sipedon*; S3), Milk Snake (*Lampropeltis triangulum*; S3), and Ringneck Snake (*Diadophis punctatus*; S3) were also absent from Cook's list which was based on total Canadian ranges. As well, these discrepancies in status attribution result from increased knowledge of species distribution and numbers acquired since Cook's list was published and from more objective criteria now applied by the CDPNQ for the province of Québec.

Eleven out of the 13 species with a high-priority conservation status in Québec were observed around the Lac des Deux-Montagnes and Lac Saint-Louis in the Montréal region making this a high-priority area for the conservation of the diversity of Québec's herpetofauna. Because these species contribute to the biodiversity of the province of Québec, conservation efforts should be directed at maintaining their local populations. In addition, the Montréal archipelago has been identified as a major sector for biodiversity conservation in Québec based on local species richness and priority index calculated for major taxonomic groups (fish, vascular plants, herpetofauna, breeding birds) (DesGranges 2000*). Although several areas are currently protected in the Montréal region, land managers need to be aware of anthropogenic pressures (e.g., pollution, habitat loss, fluctuating water levels) being exerted on remaining high-quality habitats not currently subjected to any conservation status and should act accordingly through land acquisition or stewarship programs in order to protect these communities.

Acknowledgments

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First Report of the Rare Charophyte *Nitella macounii* (T. F. Allen) T. F. Allen in Saskatchewan and Western Canada

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Mann, Henry, and M. V. S. Raju. 2002. First report of the rare charophyte *Nitella macounii* (T. F. Allen) T. F. Allen in Saskatchewan and western Canada. Canadian Field-Naturalist 116(4): 559–570.

Because few collections of *Nitella macounii* exist and early descriptions were largely based on dried herbarium material, a number of morphological features such as type and form of branching have been reinterpreted suggesting reclassification into Section Palia from Section Nitella. Earlier observations that the species may be related to *N. stuartii* are supported and a potential disjunct range with Argentina seems a possibility. Oospore membrane decoration is described in detail and conflicting earlier reports clarified. Especially significant is the first report that this species is tetrascutate, only the sixth charophyte known to be so. The ephemeral habitat and the ecology of *N. macounii* in Saskatchewan are discussed in light of the recent charophytivory hypothesis which predicts that such species are restricted to habitats where aquatic invertebrate herbivores are absent or present in low numbers. The dynamic nature of ephemeral habitats both in time and space is postulated to be a prime factor in the distribution and rarity of this species throughout its range. It is suggested that because of its unexpected ephemeral ecology, *N. macounii* may be more widespread across the Great Plains of North America than is presently known. Currently it must be considered globally and nationally very rare with only 16 known collection sites.

Key Words: Charophytes, Characeae, *Nitella macounii*, *Nitella stuartii*, *Chara braunii*, Saskatchewan, ephemeral prairie wetlands.

The charophytes of Saskatchewan and the adjacent provinces are poorly documented. Only one rather restricted survey has been carried out (Mann 1994b) confirming that few collections from the area exist and almost no descriptive or distributional literature is available. The region is rich in varied aquatic habitats, including the oligotrophic waters of the northern boreal forest, the eutrophic lakes, streams and sloughs of the prairies, saline lakes of varying sizes that dot the south, and a great variety of ephemeral and semi-permanent wetlands on the cultivated plains and the cattle ranges (Warner and Rubec 1997; National Wetlands Working Group 1988). Because a variety of habitats tend to engender a variety of species, each with its own particular adaptations to the local biotic and abiotic conditions, it should be anticipated that much taxonomic, ecological and biogeographic charophyte data will be collected from this region if and when intensive investigations are undertaken. That an aquatic charophyte flora exists in the often dry and only intermittently shallow flooded ephemeral sites of intensively cultivated grain fields is perhaps a surprise to some, but it is consistent with the broad range of ecological adaptations known for charophytes as well as recent studies such as those by Proctor (1990; 1999) from the southern extremity of the Great Plains. Our observations suggest that charophytes are common and ubiquitous in most Saskatchewan aquatic habitats and that each set of conditions fosters its own particular assemblage of species.

Here we report on several unique aspects of prairie charophytology. This is the first report of the rare charophyte Macoun's Nitella (*Nitella macounii* (T. F. Allen) T. F. Allen) from Saskatchewan and from Canada west of the Great Lakes. Features of this new distribution suggest that an expanded range may exist on the Great Plains for this species as well as a possible disjunct range with South America. Secondly, little is known about the detailed ecology of most charophyte species. We here present and discuss a somewhat novel ecological situation along with some conjectures which may lead to future investigations. Thirdly, the Saskatchewan specimens are compared to the literature and to historical collections and several issues such as oospore membrane ornamentation and antheridial structure are clarified. It is especially important to redescribe some of the significant morphological features of this species since few specimens exist and many of the details described in the literature have been derived from only a small number of plants, mostly dried herbarium specimens from which some morphological detail is difficult to interpret. Sufficient live and/or liquid preserved specimens are necessary to fully appreciate the gross morphology and range of variation normal for a species. New and re-interpreted morphological features for *N. macounii* point to a taxonomic re-alignment from the traditional view of Wood (1965).

Study Site and Methods

The core area in which *N. macounii* was discovered and intensively sought is centered in the village of Belle Plaine, Saskatchewan, located midway between the cities of Regina and Moose Jaw on the Trans-Canada Highway (Canadian Topographic Map, Drinkwater, 72-I/6, Edition 4, 1988, Grid Zone Designation 13U, Square Identification DF, Energy, Mines and Resources Canada). Belle Plaine lies within Landscape Area 17 known as the Regina Plains and within the greater ecoregion designated as Moist Mixed Grassland (Fung 1999). The area is a flat lacustrine plain with dark brown clayey soils and is almost totally cultivated. Few permanent water bodies exist in the study area. Infrequent small sloughs hold water throughout the summer in most years as do farm dugouts and road building borrow pits. Shallow depressions accumulate meltwater in spring, but by late spring to mid-summer these are frequently dry and often cultivated. Of the average annual total precipitation (380 mm), most falls during the summer months in seemingly erratic patterns over the landscape. Thunderstorms are common during the summer, often dumping considerable rain in localized areas. The apparent randomness of thunderstorm precipitation results in a patchwork of drier and wetter localized sites within the larger climatic fluctuation patterns of drier and wetter years. Areas which receive a number of spaced downpours during the season may have considerable standing water in shallow ephemeral depressions throughout the growing season, while adjacent areas may be much drier with little or no standing water (Euliss et al. 1999). As such, habitat for species adapted to ephemeral aquatic sites will exist in a dynamic flux over the landscape from season to season.

Surveys encompassed a radius of about 10 km around Belle Plaine. Four collections were made, three in 1996 and one in 2000. Site 1 (tractor rut) of 15 July 1966 has a map grid reference of 894E, 823 N. Site 2 of 18 July 1996 was within 200 meters of site 1 (an inundated fallow farm field). Site 3 of 18 July 1996 (inundated stubble farm field) has a grid reference of 882E, 823N. Site 4 of 25 July 2000 is situated in a temporary marsh/farm field with a grid reference of 872E, 729N. Visits were made to sites 1, 2, and 3 in the summers of 1997, 1998, and 1999, but they were dry early in the season and no charophytes were located. Surveys were also made in 1996 and 2000 to the north-east of Regina, east to Indian Head and the Strawberry Lakes area, as well as in the Grayson, Crooked Lake, Melville, and Yorkton areas.

Charophytes were collected by hand and either preserved in 5 percent formalin or dried as herbarium specimens. All critical examinations and measurements were made on liquid preserved material. One hundred measurements were made of each gametangial feature distributed approximately equally among at least four different individuals. Measurements and illustration are consistent with procedures described in Mann (1994b). Spore preparation for the SEM (Scanning Electron Microscope) followed the method of John and Moore (1987). Material from site 4 for chromosome counts was fixed in Farmer's Fluid and stained with the Iron Alum/Acetocarmine method of Godward (1948).

Voucher specimens of *N. macounii* are housed in the Sir Wilfred Grenfell College Herbarium (SWGC) and duplicates have been deposited with the Phycological Herbarium of the Canadian Museum of Nature, Ottawa (CANA) and with the Newfoundland Museum, St. John's (NFM). As well, Saskatchewan specimens of *Chara braunii* have been deposited with the above institutions. Herbaria abbreviations used are listed in Holmgren et al. (1990) except for SWGC which is not yet listed. The nomenclature of Looman and Best (1987) is used for vascular plants and Clifford (1991) for invertebrates.

The following specimens were examined for comparative purposes on loan from their respective herbaria: (a) Jas. M. Macoun, August 15, 1884, St. Clair River, Ontario (CANA 5840). (b) Allen and Saunders, No. 4010, August 1898, Clear Lake, South Dakota (FH). (c) Glenn Crum, No. 499, July 2, 1974, Wright County, Iowa. Sheet 1 of 3 and sheet 3 of 3 (ISC 424538 and 424539).

Morphology

Saskatchewan *N. macounii* is a small plant up to 11 cm in height arising as a single axis in dendroid fashion from a basal rhizoidal node, or in a fruticose fashion with several axes arising from the basal node. Main axes are slender and up to 600 μm in diameter. In the 2000 collection plants growing in only a few centimeters of water were very tiny, 3.0 to 3.5 cm in height. Plants are superficially very *Tolypella*-like with apparent long sterile branchlets at the lower nodes, usually more than two branches at a node, and forming small dense heads (Figure 1A). T. F. Allen (1887) indicates the species has "fertile heads" and "imperfectly formed nests", as do G. O. Allen (1954) and Crum (1975). Wood (1965) states that "heads are not formed, the entire upper parts resembling a head." Wood and Imahori (1964) state that mucus is absent, but Saskatchewan plants exhibit some mucus within the small compact heads. This feature is not mentioned elsewhere in the literature for this species; however, it is well known that small amounts of mucus are difficult to detect in dried herbarium specimens. The ability of a species to produce mucus has been used as a taxonomic character by most authors and there is some indication that it may be a useful feature in determining evolutionary radiation and dispersal in the Nitelleae (Proctor 1997).

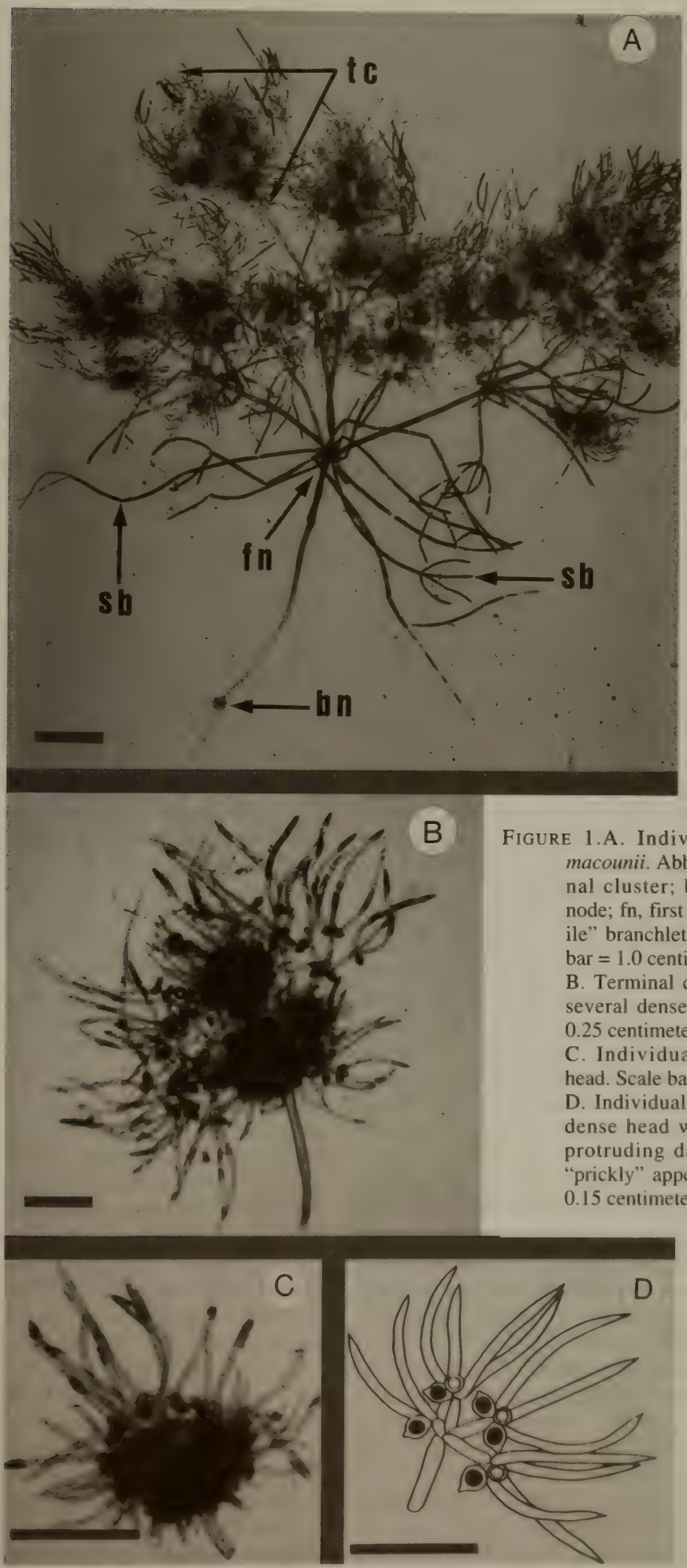

FIGURE 1.A. Individual plant of *N. macounii*. Abbreviations: tc, terminal cluster; bn, basal rhizoidal node; fn, first node; sb, long "sterile" branchlet at first node. Scale bar = 1.0 centimeter.
B. Terminal cluster composed of several dense heads. Scale bar = 0.25 centimeter.
C. Individual "prickly" dense head. Scale bar = 0.25 centimeter.
D. Individual larger branchlet of dense head which produces the protruding dactyls creating the "prickly" appearance. Scale bar = 0.15 centimeter.

At the first node above the basal rhizoidal node long "sterile" branchlets occur, up to 6.5 cm in length, sometimes simple and non-furcate with several (1–3) shorter end cells, and sometimes once or twice (rarely thrice) furcate. Originally T. F. Allen (1888) and also Wood (1948) considered this species to be heterophyllous (= heteroclemous; i.e., having branchlets of two types in a whorl); however, it is now considered to be homoeophyllous (= homoeoclemous), at most, dimorphic (G. O. Allen 1954). Some *Nitellas* such as *N. hyalina* and *N. stuartii* exhibit distinctly different branchlet forms (accessory branchlets) in their whorls (i.e., are heteroclemous) and this feature has been used taxonomically for identification purposes. In our opinion, *N. macounii* shows a heteroclemous tendency, especially in lower whorls, but it is not at all clear or well defined.

G. O. Allen (1954) states, and present authors concur, that considerable abscission and/or suppressed furcation occurs giving the appearance of deviation from the basic 2-furcate branchlet condition and producing the appearance of multicelled dactyls. Beyond the first axis node the 2-furcate, single-celled dactyl condition becomes more regular with increasing nodes. The literature (Crum 1975; Wood 1965) indicates 6–8 branchlets per node, but in the Saskatchewan material sometimes up to 12 branchlets have been noted at the first node and from 6–8–10 at subsequent nodes. Whether some of these are in fact accessory branchlets is not clear. Beyond the first node branchlets become shorter, more regularly 2-furcate (occasionally 3-furcate) and become fertile with clusters of 2–5 oogonia at the first and 1–3 oogonia at the second furcations, and a single antheridium terminating each furcation. Even a long "sterile" branchlet at the first node may very occasionally exhibit an oogonium. Antheridia appear to abscise early and can be found only on the smaller branchlets and those of the dense heads. Branchlets generally have 2–5 secondary rays, each ray bearing 2–4, occasionally 5, one-celled acute-acuminate dactyls. Dactyls of the dense heads tend to be more acuminate (Figure 1D).

Axes exhibit up to 5 nodes. Four to six branches occur at each node, the branch axis internodes becoming progressively shorter to form terminal clusters (Figure 1B) composed of smaller clusters, which themselves are composed of the tightly packed dense heads having a prickly appearance (Figure 1C). The dense center of these heads, ignoring the longer projecting dactyl tips, range from 0.1 to 0.5 cm in diameter. Dactyls of the cluster branchlets and outer dactyls of the dense heads are moderately encrusted with the sharp points of the acute/acuminate tips protruding leading one to wonder whether this "porcupine" condition of the prickly dense heads provides a mechanical deterrent to small invertebrate herbivores, perhaps especially relevant to the delicate antheridia which are mainly found in the tighter clusters and in the dense heads.

Gametangial measurements are given in Table 1 and compared to other reports for the species. Only Wood (1965) provides a full range of measurements and these are apparently taken from only two specimens, the Niagara holotype and a Wilmot, South Dakota specimen of T. F. Allen, both dried herbarium material. G. O. Allen (1954), after examining Lake St. Clair material, suggests that T. F. Allen's (1887; 1894) oospore and antheridial measurements are too low. The measurements of Crum (1975) are the largest reported. We have examined Crum's collection No. 499, July 2, 1974 which are vigorous, freely fruiting plants up to 12 cm tall. Although there is some indication that ecological factors are capable of modifying gametangial size (Griffin 1963), the extent to which this is possible is not known for the different charophyte species. The moderate differences seen in Table 1 may be considered to fall within the normal genetic variation range of the species.

At maturity the small antheridia of *N. macounii*, are greenish-yellow in live material and are tetrascutate. Most charophytes are octoscutate. No previous accounts of this species have observed this antheridial feature. Only the following five charophytes in addition to *N. macounii* are known to be tetrascutate: *Chara zeylanica* Klein ex Willd. (Proctor et al. 1971), *N. terrestris* Iyengar (Iyengar 1958), *N. stuartii* A. Braun (Carl de Donterberg and Rotman 1973), *N. cordobensis* Caceres (Caceres 1975), and *N. quadriscutulum* Jao and Li (Han and Li 1994). Tuttle (1924) also mentioned a tetrascutate charophyte from Virginia but it is not possible to verify this or determine the taxon. Because the tetrascutate condition is difficult to determine from dried herbarium specimens, especially in species with tiny antheridia whose plates do not separate easily, this feature may be more common in charophytes than is presently known. Most species descriptions in the literature make no reference to the number of antheridial scutes. The tetrascutate feature has been shown to be taxonomically significant in the elucidation of the *Chara zeylanica* complex (Proctor et al. 1971) and may also prove to be so in the genus *Nitella*.

Oospore membrane decoration has long been considered an important taxonomic feature in the genus *Nitella* (Groves and Bullock-Webster 1920). More recent studies with the SEM have further elucidated details of membrane ornamentation in selected species (Frame 1977; John and Moore 1987; Casanova 1991). The strongly ornamented oospore of *N. macounii* is very characteristic of the species, yet considerable discrepancy exists in the literature. T. F. Allen originally described it as smooth due to the lack of mature spores in the original collection, but later upon receiving material with mature oospores described it as having a surface marked by short elevations like mountain peaks, somewhat

TABLE 1. Gametangial and oospore features of *Nitella macounii*. Measurements are presented as means (μm) with range values in parentheses.

	This study 2002	T. F. Allen 1887 & 1894	G. O. Allen 1954	Wood 1965	Crum 1975
Oogonium					
length*	386 (341–413)	–	–	(345–360)*	(350–450)
width	283 (248–310)	–	–	(255–270)	(320–350)
coronula height	44 (36–52)	–	–	(42–53)	–
coronula width	65 (52–72)	–	–	(60–80)	–
convolutions	(6–8)	–	–	(7–8)	7
Oospore					
length	243 (207–248)	(210–215)	275	(225–240)	(260–280)
width	241 (207–248)	(200–210)	250	(180–225)	(240–260)
No. of ridges	(4–6)	(5–8)	(5–6)	(5–8)	(5–6)
fossae width	53 (41–62)	–	–	42	–
Antheridium					
diameter	191 (165–227)	130	–	(195-225)	(200-250)

*All measurements include coronula height except Wood (1965) which does not.

elongate and arranged irregularly at right angles over the fossae surfaces (T. F. Allen 1894). Wood (1948) describes it in the same fashion, but later (Wood 1965) states it is "strongly vermiferous, the irregular raised areas occasionally becoming imperfectly reticulate." G. O. Allen (1954) does not consider T. F. Allen's (1894) description and illustration to be accurate, but describes it as a "coralloid reticulum, i.e. a deeply sculptured but imperfect reticulum, looking rather as if some fish-netting had gone rotten and became broken in many places." Crum (1975) simply states the membrane to be strongly discontinuous reticulate. The only SEM view of this species (Frame 1977) concludes the membrane to be papillate-reticulate to strongly reticulate when mature.

The present study demonstrates that all of the above views on the oospore membrane decoration of *N. macounii* have some validity, but they each only address a part of the total picture presumably due largely to a small number of plants and oospores examined. The present study has had available a considerable number of different plants collected from four localities and liquid preserved. Large numbers of oospores which had washed free of their plants and which had been naturally "released" from their enveloping cells could be and were examined. It became quickly apparent that all naturally shed oospores were not alike. All appeared fully formed and apparently viable, but existed in three distinct ranges as seen with reflected stereoscopic light: pale golden-yellow, pale orange-brown, and dark orange-brown. Quantitatively, these were approximately present as 10 percent, 20 percent, and 70 percent respectively. Literature reports for oospore color include dark brown (Wood 1965), dark chestnut brown (Wood and Imahari 1964), and deep golden-brown (Crum 1975). The pale golden-yellow spores exhibit a distinct fine reticulum with approximately 9–11 reticulation meshes across a fossa (Figure 2D). At the other extreme, the darkest orange-brown spores exhibit a distinct tuberculate series of irregular raised areas as described and illustrated by T. F. Allen (1894), Wood and Imahori (1964), and Wood (1965). This pattern is clearly seen in the SEM Figure 2A, B. Focusing slightly down with the light microscope, near the base of the flaring tubercles, will produce a coarse reticulate view. Casanova (1991) also noted this discrepancy between SEM and light microscope views. The intermediately-colored pale orange-brown spores have an appearance somewhat intermediate between the fine reticulation and the coarse tuberculate which might be described as an imperfect "rotten fish-net" reticulum (Figure 2C). Specimens examined on loan (CANA, FH, and ISC) exhibited similar membrane features as those described here. At certain stages *N. macounii* membrane decoration resembles that of Casanova's (1991) *N. stuartii*, but even more resembles her tuberculate spores of *N. pseudoflabellata*. It seems clear that more studies like the present and Casanova (1991) showing the range of ornamentation produced by a taxon are necessary if we are to fully understand the taxonomic significance and limitations of this feature.

In the traditional view, the pale golden-yellow spores represent immature spores and the darkest those that are fully mature. All studies are based on this assumption which has not been critically tested. Since all of these spore types of *N. macounii* are naturally shed, they might be considered equally mature, or are immature spores at various stages of development also naturally shed? Can the ornamentation of spores further develop after they have been shed? Or is it possible that in this species and others fully mature polymorphic spores are produced, genetically determined, as would be analogous to well known examples of seed polymorphy in some of the angiosperms (Harper et al 1970)? The litera-

ture seems to be blank on these questions. It may be suggested that having the ability to produce a variety of spore types with varying wall thicknesses related to length of dormancy would be ecologically advantageous to a species utilizing ephemeral habitats which shift spatially and temporally with the vagaries of the climate and seasons. Casanova and Brock (1996) describe timing variation (i.e., polyphysiologic spores) in spore germination of species adapted to ephemeral sites. There seems to be no reason why this feature may not also exhibit a morphological expression, at least in some charophytes. In the absence of conclusive evidence, we can only speculate on this matter at present.

Taxonomy

Nitella macounii (T. F. Allen) T. F. Allen was first described by Allen from two specimens sent to him by J. M. Macoun collected at Niagara Falls in 1882 (T. F. Allen 1887). Because of its *Tolypella*-like habit, Allen originally named it *Tolypella macounii*, stating "This is one of the most remarkable Tolypellae that has yet been described .... It is Nitella-like in its habit of growth, slightly encrusted, and altogether unique." G. O. Allen (1954) examined one of the original Niagara type locality specimens and could find no "ripe fruit" which due to its flattened structure would have indicated a Nitella rather than a *Tolypella*. After receiving additional specimens which clearly showed terminal antheridia collected by Macoun from Lake St. Clair, T. F. Allen renamed the plant *Nitella macounii* (T. F. Allen 1888). Allen again published a brief description of the species in his *Characeae of America* series (T. F. Allen 1894). Subsequent descriptions by R. D. Wood (1948; 1965) utilized earlier descriptions and the examination of one and two specimen collections respectively. G. O. Allen's *Annotated Key* (1954) provides some useful observations on branchlet structure and oospore membrane decoration. The most recent brief description is from Iowa by Crum (1975).

Wood (1965) includes *N. macounii* in Subgenus *Nitella* characterized by one-celled dactyls, and in Section Nitella with non-acuminate dactyl apices. Later in his description of *N. macounii* Wood contradicts this distinction by stating that dactyl apices are acuminate. Included in Section Nitella is Wood's *N. flexilis* group and *N. mirabilis*, both producing one-furcate branchlets, whereas *N. macounii* has 2-furcate branchlets.

Tindall (1967) in describing a new species of *Nitella* (*N. hotchkissii*) from the southwestern USA, suggests two similar species groups, the *N. flexilis* group (including *N. flexilis, N. opaca, N. missouriensis, N. mirabilis, N. hotchkissii*) and the *N. acuminata* group (including *N. acuminata, N. stuartii, N. allenii, N. macounii*). Both groups show parallel morphological features and each shows a distinct polyploid series of chromosome numbers, n = 6–12 in the *N. flexilis* group and n = 9–18 in the *N. acuminata* group. Chromosome numbers for *N. macounii* are not known. Attempted counts in this study were unsuccessful. Although staining was adequate, good chromosome separations were not obtained and it appears that future attempts may require some pre-treatment in order to obtain the necessary chromosome separation.

Frame (1977) suggested that *N. macounii* be transferred to Subgenus *Hyella* based on it "often having two-celled dactyls" and that the membrane "was imperfectly to strongly reticulate." In our opinion there seems to be no sound basis for such a conjecture.

Carl de Donterberg and Rotman (1973) describe a *Nitella* from Argentina which they determine as *N. stuartii* A. Braun, the first report of this species in the Americas. Their plants exhibited features of both *N. stuartii* and *N. allenii*. Wood (1965) suggests that the two originally described from India and the Pacific region may in fact prove to be conspecific. John and Moore (1987) also suggest a possible conspecificity based on oospore membrane ornamentation. The Argentina *N. stuartii* is remarkably similar to North American *N. macounii* both in the description and illustrations. Both are tetrascutate. They appear to differ in only two, perhaps superficial ways. *N. stuartii* has slightly larger oogonia and oospores than *N. macounii*, but otherwise morphologically similar in terms of convolution number and oospore membrane decoration. A full detailed membrane appraisal as presented here for *N. macounii* is not available for the Argentina material; however, it is reported as being reticulate. Antheridia are of similar size. The Argentina specimens are described as "occasionally heteroclemous" whereas *N. macounii* is now thought to be homoeoclemous (G. O. Allen 1954); however, as discussed earlier, it has heteroclemous tendencies and Wood (1965) also indicates there is variability in this feature between *N. stuartii* and *N. allenii*. There is a possibility that North American *N. macounii* and Argentina *N. stuartii* may be conspecific, and if not, they must surely be closely related. Examples of such charophyte conspecificity between the two regions are *Nitella cordobensis* (Proctor 1999) and *Chara longifolia* (Proctor et al. 1967). A number of vascular disjuncts between the Pampas of Argentina and the Great Plains of North America are also well known (Raven 1963).

T. F. Allen (1888) originally suggested that *N. macounii* be placed close to *N. stuartii* and our present knowledge still seems to support his view. Even using Wood's (1965) own criteria, this species seems to show a greater affinity with Section Palia than where it was placed in Section Nitella. Interestingly, the tetrascutate *N. quadriscutulum* reported from China (Han and Li 1994) is heterophyllous and exhibits similarities to *N. stuartii* as well as North American *N. macounii*. However, unlike the Argen-

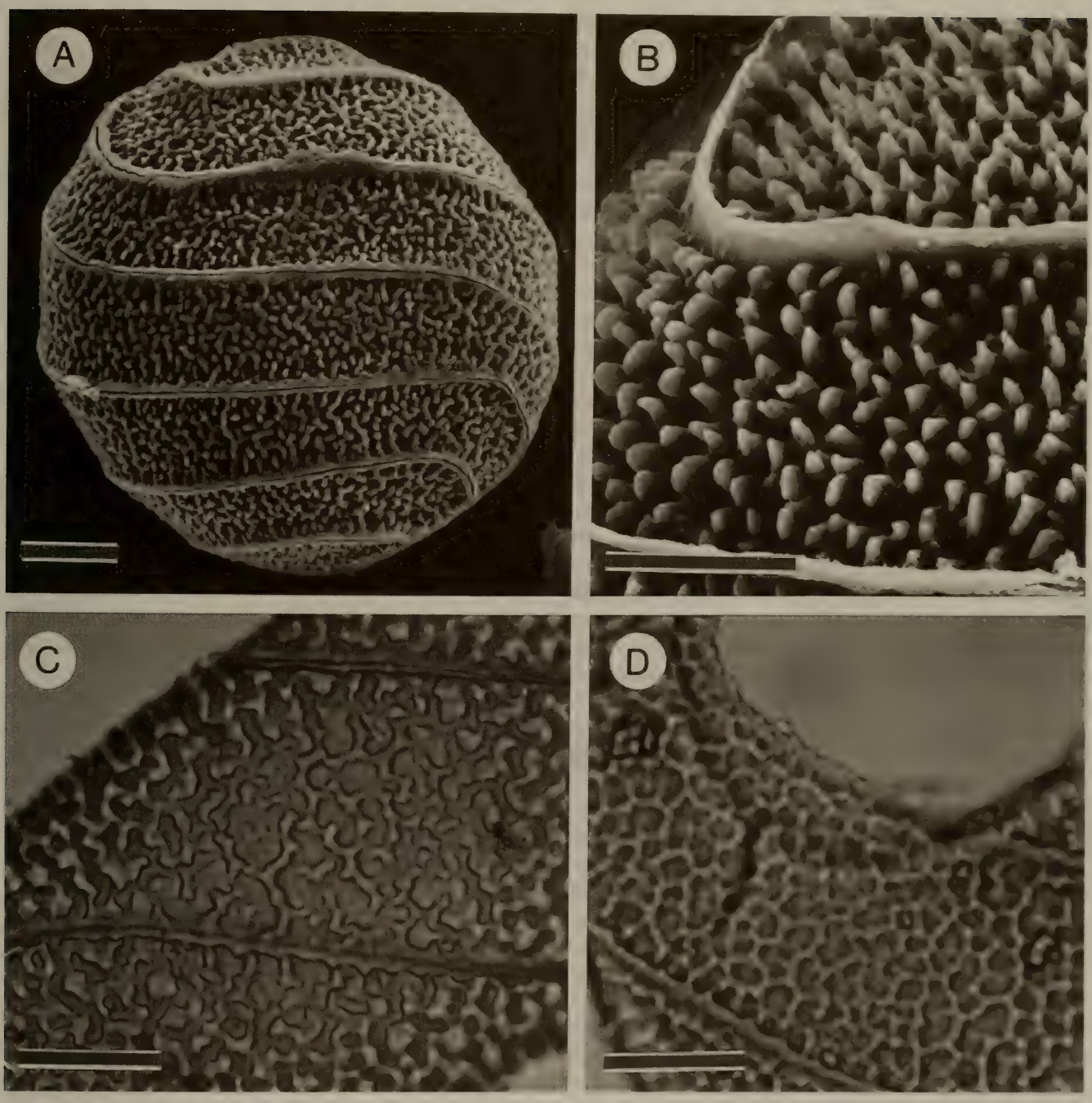

FIGURE 2. A. SEM photo of tuberculate dark orange-brown oospore. Scale bar = 40 micrometers.
B. Enlarged SEM photo of tuberculate oospore membrane, flaring contiguous bases of tuberculae seen in upper portion of photo. Scale bar = 25 micrometers.
C. Light photo of a pale orange-brown oospore membrane showing discontinuous reticulation, "rotten fishnet" appearance. Scale bar = 25 micrometers.
D. Light photo of golden-yellow oospore membrane showing a fine naticulate mesh. Scale bar = 25 micrometers.

tina taxon designated as *N. stuartii* (Carl de Donterberg and Rotman 1973), the Chinese *N. stuartii* taxon is reported to be octoscutate. It has been demonstrated that tetrascutate and octoscutate members of a "species group" are reproductively isolated in *Chara* (Proctor et al 1971). Such a major structural difference in a gametangium probably suggests reproductive isolation in the genus *Nitella* as well, supporting the view that the entire *N. stuartii* complex needs re-evaluation. John and Moore (1987) also suggest that the *N. stuartii* species as it is presently constituted needs reappraisal.

At this time it is not possible to be any more definite about the taxonomic relationships of *N. macounii*. In light of more recent concepts of evolutionary pathways (Proctor 1980; Meiers et al. 1999) it is clear that some of Wood's (1965) views on relationships are no longer tenable and that a reappraisal of the entire genus using modern concepts and techniques is necessary.

For practical identification purposes, *N. macounii* is the only known monoecious North American species with single-celled acuminate dactyls that is basically 2-furcate and has the highly ornamented oospore membrane discussed in this paper. It is also the only known tetrascutate *Nitella* in North America with single-celled dactyls and a reticulate/tuberculate oospore membrane. The somewhat similar *N. cordobensis* is tetrascutate, but has multicellular dactyls and a spongiform oospore membrane.

Ecology

The early reports of *N. macounii* provide no information about the abiotic or biotic ecology of the species. The first and only sparse information comes from the Ph.D. thesis of Crum (1975) from Iowa. All four Iowa collections were from pond margins/marshes with their characteristic submerged and emergent plants and which periodically became dry. Crum speculates that some disturbances to limit the cover of other macrophytes may be necessary to provide suitable habitat and suggests that even a single hoof print may provide such.

The Saskatchewan collections all came from ephemeral sites. The year of 1996 was unusually wet in the study area with much standing shallow water in low lying areas of fields that would normally be cultivated in drier years. Our initial discovery location (site 1) was a shallow tractor wheel rut in a grassy highway ditch adjacent to a natural marsh and a cultivated grain field. On the collection date of 15 July 1996 the water had receded into the marsh and the grassy ditch, although wet, contained no standing water, whereas the rut was still inundated. Here, in less than 10 cm of water, were growing scattered plants of *N. macounii* in association with *Chara braunii*. In the adjacent shallow marsh margins *Chara globularis* (= *C. fragilis*) was commonly noted. A search of the inundated areas of the nearby cultivated fallow field (site 2) led to the discovery of scattered plants of *N. macounii, C. braunii, Tolypella prolifera*, and *C. globularis* (= *C. fragilis*) in shallow, warm, clear water of less than 20 cm depth, sometimes only a few centimeters. Subsequent searches of the Belle Plaine area turned up a third site in an inundated depression of a grain field. Here, in water 30 cm or so, *N. macounii* grew to its lushest stature with a considerable number of scattered plants amongst the submerged grain stubble of the previous year. Plants of all three collections had produced ripe oospores on the larger outer branchlets of the terminal clusters, but the tiny branchlets of the dense heads contained mostly immature gametangia.

In only one of the three collection sites (site 1) were invertebrates conspicuous, whereas net sweeps in the marsh adjacent to sites 1 and 2 amongst the *C. globularis* captured significant numbers and kinds of invertebrates. Included were two species of Gastropoda (snails), one species of Cladocera (water fleas), two species of Hydrachnidia (water mites), one species of Amphipoda (scuds — *Hyalella azteca*), one species of Corixidae (water boatmen), one species of Copepoda (copepods) two species of Chironomidae larvae (midges), three species of Coleoptera, Hydrophilidae larvae (water beetles) including *Berosus* sp., and one adult hydrophilid beetle. *Hyalella azteca* is a species indicative of permanently inundated sites as it has no life cycle stages capable of surviving drying or freezing periods (Wiggins et al 1980; Batzer and Sion 1999).

Site 1 (tractor rut) had possibly been shallowly connected to the receding marsh waters and harbored a number of invertebrate types including snails, water boatmen, leeches, and water mites; amphipods were looked for, but not found. The amphipod *H. azteca* is known to be a significant grazer on charophytes under certain conditions (Proctor 1999). Net sweeps of site 3 where *N. macounii* grew vigorously amongst the grain stubble revealed no invertebrates. Site 2 only exhibited an occasional adult hydrophilid beetle. Neither site 1 nor 2 was swept with a net due to the shallowness of the water, but were carefully examined visually and observed invertebrates were collected.

The years since 1996 were much drier in the study area and yearly visits to the collection sites noted that they had dried early in the season and consequently no charophytes were found. In 2000 the sites were also dry, but some shallow waters were located on surveys radiating outward from Belle Plaine in mid-July. All of these sites were very shallow; however, in many years they retained water into July and August as evidenced by the growth of aquatic and semi-aquatic vegetation including the following: *Alisma plantago-aquatica* L. (Common Water-plantain), *Typha latifolia* L. (Common Cattail), *Beckmannia syzigachne* (Steud.) Fern. (Slough Grass), *Callitriche* sp. (Water-starwort), *Elatine triandra* Schkuhr (Mud-purslane), *Gratiola neglecta* Torr. (Clammy Hedge-hyssop), and *Limosella aquatica* L. (Mudwort). In deeper depressions and adjacent ditches aquatics such as *Potamogeton* (Pondweeds) and *Sparganium* (bur-reeds) could be found. The shallower parts of the sites were dry by early August 2000. In a number of these locations where the growth of vascular plants was sparse and exposed muddy substrate was available, *Chara braunii* was commonly found as numerous scattered individual plants. In only one such site on 25 July 2000 (site 4) in about 6 cm of water in association with *C. braunii*, three tiny plants of *N. macounii* were located. Up to the present, only one record of *C. braunii* existed for the Canadian Prairies (Mann 1994b). Unlike *N. macounii* it is a well known and widely distributed species elsewhere in North America and beyond whose ecology can perhaps shed some light on that of *N. macounii*. In Proctor (1990) it is characterized as "a eurytherm adapted to shallow water"

and "a superb fugitive or opportunistic species as well." In the ephemeral playas of the Texas Panhandle and adjacent areas it is the most frequently encountered charophyte noted for the "— extreme precociousness with which individuals set gametangia and in turn oospores, during the warmest months of the year. It is not at all exceptional to encounter gametangia and later oospores, at the second and succeeding nodes when individuals are but 1.0–1.5 cm above the mud-water interface." The meager available observations from this study and that of Crum (1975) suggest that *N. macounii* to some extent parallels the above features of *C. braunii*; i.e., it is a small, rapidly growing and sporulating charophyte of ephemeral sites. However, some more specific habitat difference does appear to exist between the two. *N. macounii* produced the best growth in the inundated grain fields, sites often dry and cultivated for years between flooding episodes. *C. braunii* may or may not be present in these sites. *C. braunii*, on the other hand, seems to prefer shallow ephemeral habitats that were inundated more regularly as evidenced by more permanent aquatic and wetland vegetation species.

Proctor (1990) noted that two distinct types of aquatic habitats exist in the Llano Estacado, the ephemeral playas characterized by eleven charophyte species including *C. braunii* and *Tolypella prolifera,* and permanent sites characterized by nine other species. The two charophyte assemblages never overlap in the same water body. Although definitive surveys have not been made, observations also suggest that like the Texas situation, two distinct charophyte floras may exist in the Belle Plaine area, that of ephemeral sites and that of permanent sites, although with fewer and some different species. *Chara globularis* (= *C. fragilis*) is present in almost every permanent site in our study area. At one ephemeral site (site 2) adjacent to a permanent marsh, a few plants of *C. globularis* were encountered. None of *C. braunii*, *N. macounii* or *T. prolifera* have yet been located in permanent sites in the study area. *Chara globularis* is also known as a herbivore resistant species (Mann et al 1999).

The Charophytivory Hypothesis has been proposed by Proctor (1997; 1999) to explain the ecological distribution of charophyte species. According to this conjecture, invertebrate herbivory has been a major driving force in the evolutionary development of physiological, morphological, and ecological adaptations. Some species have evolved adaptations which render them relatively herbivore resistant and therefore allow them to flourish in permanent water bodies often containing high concentrations of herbivores, notably amphipods, certain aquatic beetles, crayfish, etc. These adaptations may include such features as heavy encrustation, thick cell walls, numerous sharp spine cells, mucus production, vegetative reproductive mechanisms, deterrent chemistry, and others. Species lacking these adaptations would be largely excluded from waters with high herbivore populations, but could flourish in ephemeral habitats where herbivores were absent or present in low numbers. Adaptations to these habitats could include rapid growth and sporulation, highly resistant, long-lived spores, physiological adaptation to growth in very warm shallow water, and others.

Although the early collections of *N. macounii* were apparently made from permanent large water bodies, the Great Lakes and their rivers, a few clues in the literature and on specimen labels suggest that this is not incompatible with the "two floras" and "charophytivory" concepts. T. F. Allen (1887) states that Macoun's original collection came from "a pool on the shore of the Niagara River above the Falls." The label on the herbarium sheet of Carl O. Grassl, No. 2097, 1932 (MICH) states "In shallow water below rapids on east side of French River Harbour ...." Side pools of rivers often become isolated as water levels drop in the summer and may become very shallow or dry periodically. Both ephemeral waters and flowing waters moderate the diversity, spatial distribution and density of invertebrates compared to non-flowing permanent sites (Williams 1987; Giller and Malmqvist 1998). *Chara braunii* is also known from the Great Lakes region and the Charophytivory Hypothesis predicts that both these species will only be found in waters of low herbivore pressure. Early collections have come from the Great Lakes region largely because most northern field work has been done there. This is evident by the charophyte collections in CANA where the largest number of Canadian collections are from Ontario. Unfortunately few collections include any useful habitat data on their labels.

This species, like *C. braunii*, therefore appears to be a herbivore susceptible "avoider" of sites where high specific invertebrate populations occur. Ephemeral sites provide one such widely dispersed favorable type of habitat. However, deeper and permanent water bodies having favorable biotic and abiotic conditions also certainly exist where both these species could flourish. In deeper waters it may be expected that plants would be larger and more lax as has been noted in other species such as *Tolypella glomerata* which appears to have some parallel adaptations and habitat preferences to *C. braunii* and *N. macounii* (Mann 1994a). Should *N. macounii* become readily culturable, a number of ecological hypotheses could easily be tested under controlled conditions.

Little is known about the growth characteristics and life cycle of *N. macounii*. Morphologically it appears to be an annual exhibiting determinate growth. No signs of growing tips (apical meristems) can be found in the small dense heads which ultimately terminate all branches of mature fruiting plants. Like annual seed plants, it appears to grow quickly under favorable conditions and to put all its

energies into the rapid production of sexually produced propagules. Whether, like some *Tolypellas*, it can also behave as a winter annual is not known. Its growth in ephemeral habitats as individual scattered plants arising from a single rhizoidal node also suggests its annual nature. No evidence of clonal growth has yet been noticed.

Distribution

Nitella macounii was first collected at Niagara Falls, Ontario, in 1882, and including Crum's (1975) reports, only 12 collections were known until the four reported in this paper. The general distribution is centered in three major areas, the Great Lakes of southern Ontario, northern Iowa/north-eastern South Dakota, and south-central Saskatchewan as illustrated in Figure 3 (G. O. Allen 1954; Crum 1975). Current records from Saskatchewan are in excess of 800 km from the closest South Dakota collections and 1900 km from the nearest Canadian site.

In this study and also that of Crum (1975) *C. braunii* is very often a companion of *N. macounii*. Assuming equal dispersal capabilities, why then are the ranges of the two species so different? *C. braunii* occurs right across the continent from southern Canada to Mexico, whereas *N. macounii* is restricted to a small region of the north-central continent. One part of the answer, no doubt, is that *C. braunii* has a broader ecological tolerance to biotic and/or abiotic conditions, but exactly what these are is not known at present. Another conjecture is that *N. macounii* is a relatively recent disjunct immigrant from South America, the result of an uncommon long distance dispersal event, and is now undergoing adaptation and dispersal in its new environment.

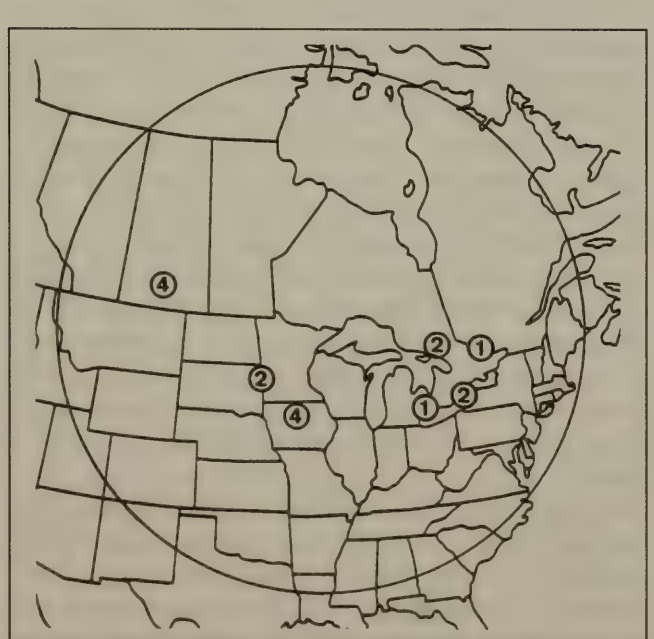

FIGURE 3. Distribution map of *N. macounii*. Each number refers to the number of individual collections from the region.

A third possibility, highly probable, is that *N. macounii* is in fact more widely distributed across the continent than is known at present. Only a few areas of North America have been thoroughly surveyed for charophytes and many gaps still exist. Disturbed and intermittently inundated habitats tend to be under-collected including much of the prairie biome which has been cultivated, in some areas almost totally. This applies equally to the vast cattle ranges of the plains, many of which are not readily accessible by usual means. It may be that pockets of suitable habitat are widely separated within the greater prairie biome. For example, surveys to the north and east of Regina as far as Grenfell, Melville and Yorkton turned up no habitat precisely like that around Belle Plaine and neither *C. braunii* nor *N. macounii* were ever encountered. There the landscape is more rolling, rainfall tends to be slightly higher, and permanent sloughs and lakes become more frequent. The most common charophytes of these sites are *Chara contraria* and *C. globularis* (= *C. fragilis*), species highly resistant to invertebrate grazing pressure. Equally instructive is the absence of both *N. macounii* and *C. braunii* from Newfoundland and other parts of North America where ephemeral or herbivore-free sites are unknown or very rare.

Nitella bastinii is an example of a recent expansion of our knowledge of a North American range. It was first described from Chicago in 1890 (Wood 1965) and not until 1975 was a second report made from Iowa (Crum 1975), and then it was subsequently reported as widespread in the playas of Texas (Proctor 1990).

Most of the reports of *N. macounii* come from the prairie pothole region of the Great Plains, Saskatchewan through South Dakota and Iowa. Of all the wetlands in this region, the temporary wetlands are most vulnerable to agricultural modification (Kantrud and Newton 1996). These are often cultivated in the drier years of climate cycles and are subject to direct applications of herbicides, pesticides and fertilizers. Whether these factors are offsetting the increased habitat creation of cyclic cultivation and inundation remains to be determined. In our limited surveys of 1996 and 2000, no charophytes were found in shallow inundated areas that had obviously been sprayed in the Belle Plaine study area or elsewhere.

At the moment, based in 16 known collections centered in three somewhat restricted areas of North America, *N. macounii* must be considered very rare, globally, continentally, as well as nationally (Canada = 10 sites, U.S.A. = 6 sites). Due to the dynamic nature of suitable habitat shifting yearly both in time and space and tied to the vagaries of local climatic oscillations, it may be difficult to obtain meaningful survey results to verify this rarity status.

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Plant Community Composition and Relationships of Disturbed and Undisturbed Alvar Woodland

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In order to quantify the difference between a recently disturbed and undisturbed alvar woodland, thus indicating the impact of disturbance, and to determine differences in the effects of bulldozing and burning, we analyzed quadrat data and compared species lists from four situations: (1) a burned area 100 days after the fire, (2) the same burned area a little more than a year after the fire, (3) bulldozed tracks through unburned woodland a little more than a year after bulldozing, and (4) adjacent unburned woodland. Correspondence analysis and coordinate analysis based on distance coefficients suggested that the greatest differences were between unburned woodland and burned woodland 100 days after the fire. Bulldozed tracks and burned woodland more than a year after disturbance occupied an intermediate position. It appears that initially after a major disturbance event involving both removal of woody biomass and soil disturbance, mixed or conifer-dominated alvar woodland develops a very different plant community which is quickly replaced by one that more closely resembles the unburned woodland. Species strongly or exclusively associated with unburned woodland included (in descending order of suggested association): *Abies balsamea*, *Arctostaphylos uva-ursi*, *Waldsteinia fragarioides*, *Rhamnus frangula*, and *Carex eburnea*. Species particularly associated with unburned woodland and bulldozed tracks were: *Cypripedium parviflorum* var. *pubescens*, *Prunella vulgaris* and *Bromus kalmii*. At the other end of the scale, species associated with alvar woodland burned 100 days earlier were (in descending order of importance): *Calystegia spithamea*, *Viola* cf. *adunca*, *Populus tremuloides*, *Maianthemum canadense*, *Corydalis aurea*, *Scutellaria parvula*, *Geranium bicknellii*, *Dracocephalum parviflorum*, *Rhus radicans* ssp. *negundo*, and *Aralia nudicaulis*. *Verbascum thapsus* and *Potentilla argentea* and a number of other introduced species were uniquely associated with bulldozed tracks. Since burning was associated with fewer alien colonizers than bulldozing, it is potentially a more desirable form of disturbance management, but bulldozed tracks did include many native species. Alien species may decline over the longer term. Disturbance management, involving woody biomass removal and substrate disturbance, is an important consideration in maintaining biodivesity at both the community and species levels in alvar landscapes.

Key Words: alvar, fire, bulldozed, flora, species diversity, rare species, succession, management, biomass removal, burn, prescribed burn, soil, Great Lakes, Ontario, Canada.

While the importance of alvars as unusual and imperiled ecosystems containing rare and restricted species has been known for some time (Catling and Brownell 1995, 1999; Brownell and Riley 2000), the importance of alvar woodland and its associated successional stages, particularly "successional alvar burns" had escaped attention until very recently (Catling and Brownell 1998; Brownell and Riley 2000; Catling et al. 2001). With the evidence that disturbance in woodland adjacent to alvar openings initiates a succession contributing to a high biodiversity and permits the occurrence of rare native species, the question arises as to how important this disturbance is and how it should be maintained.

The extensive fire on the Burnt Lands Alvar northwest of Ottawa on 23 June 1999, which consumed 152 hectares of mostly forested terrain near Almonte (e.g., Catling et al. 2001), provided an opportunity to gather data that would answer some of these questions regarding importance of disturbance and effects of different kinds of disturbance management. Here we compare vascular flora in four situations: (1) a burned area shortly after the fire, (2) the same burned area a little more than a year after the fire, (3) bulldozed tracks through unburned woodland, and (4) adjacent unburned woodland that had evidently been undisturbed since the 1870 fire 130 years ago, which gave rise to the name "The Burnt Lands". The specific purposes were to: (1) quantify the difference between the recently disturbed and undisturbed situations, thus indicating the value of disturbance, (2) determine differences in the effects of bulldozing and burning, and (3) outline the floristic composition of the very earliest stages in the succession of fire prone alvar woodland.

Methods

The Burnt Lands alvar is located in the county of Lanark and the City of Ottawa (formerly Regional Municipality of Ottawa-Carelton, see Brunton 1986*; Brownell and Riley 2000) on the Smith's Falls Limestone Plain in eastern Ontario. The sites specifically studied are centred on 45.2559 °N, 76.1432 °W, and detailed descriptions of the actual positioning of

* See Documents Cited section.

transects are on file with the Kemptville office of the Ontario Ministry of Natural Resources. The portion of the Burnt Lands that was burned and bulldozed was mostly dry alvar woodland dominated by *Thuja occidentalis*, *Populus tremuloides*, *Abies balsamea*, *Picea glauca*, and *Pinus strobus* (Catling et al. 2001).

One m^2 quadrats were set out at 5 m intervals along transects in four different stages of vegetation development in alvar woodland: (1) burned woodland 100 days after a severe fire (using 250 quadrats with data collected 1–7 October 1999); (2) burned woodland 465 days after the fire (using 150 quadrats of which 140 were in essentially the same positions as for (1) with data collected in October 2000); (3) non-driven portions of bulldozed tracks through unburned alvar woodland 465 days after the bulldozing which was done in connection with the fire control (using 100 quadrats with data collected in October 2000); and (4) unburned alvar woodland adjacent to the burned woodland and bulldozed tracks (using 100 quadrats with data collected in October 2000). For each quadrat, the total cover (estimated as the upper leaf surface area in dm^2) of each plant species was recorded for all vascular plants within 1 m of the ground. Using an estimate of the photosynthetic surface area of the plants rather than the surface area of the quadrat covered by that species permits a more direct correlation between cover values and biomass. The total cover and total frequency for each species at each site was calculated and total overall cover and total overall frequency were tabulated (Table 1.).

In order to obtain an analogous plot for row and column variables based on weighting according to species frequencies, correspondence analysis was employed (for computational outline see Lebart et al. 1984). The analogous plot allows points in one set, in this case communities, to be generally associated with maximum representivity in the other set, in this case species, based on similar positions in the plots. The matrices of squared correlations were used to determine the relative importance of each factor for each species and community. The relationship among communities was additionally evaluated using principal coordinate analysis based coefficients of average taxonomic distance. A minimum spanning tree derived from distance coefficients for percentage frequency factors, percentage frequency coordinate axes, and total cover coordinate axes was superimposed on the community plots in correspondence analysis, frequency coordinate analysis, and cover coordinate analysis (respectively). This enabled the relationship between communities to be evaluated with maximum accuracy within the framework of a general pattern.

Scientific and common names generally follow Newmaster et al. (1998). Voucher specimens for some of the species recorded were deposited in the vascular plant herbarium of Agriculture and Agri-food Canada (DAO) in Ottawa.

Results and Discussion

Correspondence analysis and coordinate analysis based on distance coefficients (Figures 1 and 2) suggested that the greatest differences were between unburned woodland and burned woodland 100 days after the fire. Bulldozed tracks and burned woodland more than a year after disturbance occupied an intermediate position. This is well portrayed in both the correspondence analysis and coordinate analysis, with the curved line of the MST graph having unburned woodland at one end and recently burned alvar woodland at the other. For the correspondence analysis, squared correlations for four different alvar woodland plant communities (Table 2) indicate that factor 1 is most important for separation of unburned and very recently burned woodland. Factor 2 is important for the separation of unburned woodland from the other communities, but especially from bulldozed tracks. Factor 3 is mainly concerned with the separation of the bulldozed tracks from the woodland burned more than a year earlier. Since almost half (46.17%), of the variation in the sample relates to the axis (factor 1) separating the unburned and very recently burned woodland community, it is clear that the very earliest stage of succession is the most different. It appears that initially after a major disturbance event involving both removal of woody biomass and soil disturbance, mixed or conifer-dominated alvar woodland develops a very different plant community which is quickly replaced by one that more closely resembles the unburned woodland. Communities developed more than a year after the fire occupy an intermediate position on the first axis and are separated from the recently burned woodland on the second axis accounting for 34.22%. This is supported by the fact that there is a rapid return to a community that more closely resembles the unburned

TABLE 1. Squared correlations for four different alvar woodland vascular plant communities indicating relative importance of three factors in correspondance analysis.

Community	Factor 1	Factor 2	Factor3
unburned	0.548479	0.436791	0.014730
burned 100 day ago	0.693909	0.255534	0.050558
burned 465 days ago	0.114174	0.222520	0.663307
bulldozed	0.184411	0.433554	0.382034

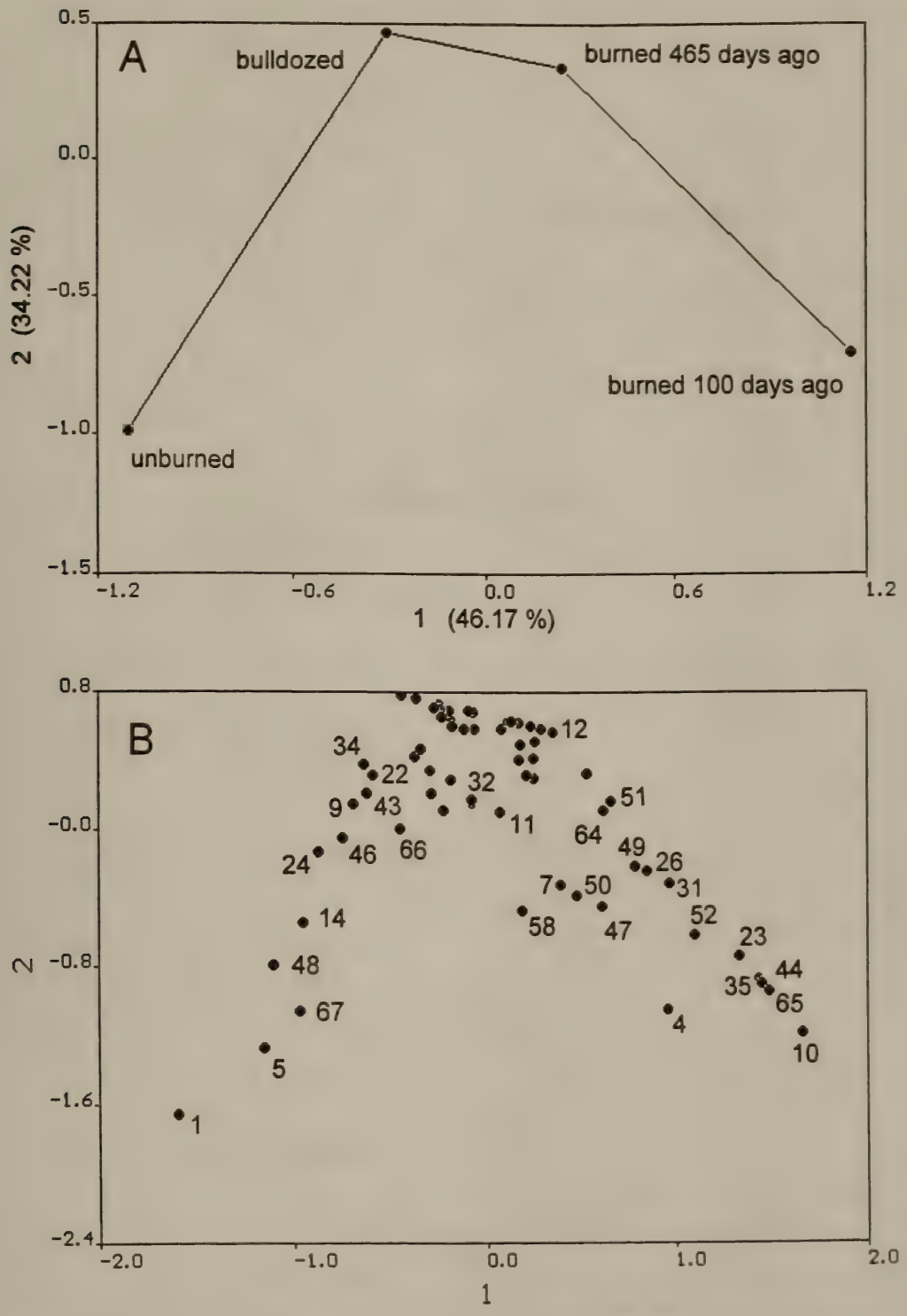

FIGURE 1. A, plot of four alvar woodland plant communities based on correspondance analysis of % frequency data. The nearest neighbour of each community is joined by a straight line forming a minimum spanning tree. B, corresponding plot of species suggesting representivity in particular communities. Numbers correspond to species listed in Appendix 1.

woodland. With 80.39% of the variation largely related to the separation of disturbed and undisturbed alvar woodland communities, it is clear that most of the variation in the data can be explained by presence or absence of disturbance and disturbance can lead to major changes in community composition. The unburned woodland contributes most to the first two axes and relatively little to the third (Table 1).

Unburned woodland was most closely related to bulldozed tracks through unburned woodland, probably because bulldozing shallow soil over cracked and slightly uneven limestone pavement does not eliminate all of the established flora. In addition, there is a very close seed source for rapid recolonization of woodland species. The relatively close relationship of the older (more than one year) burned

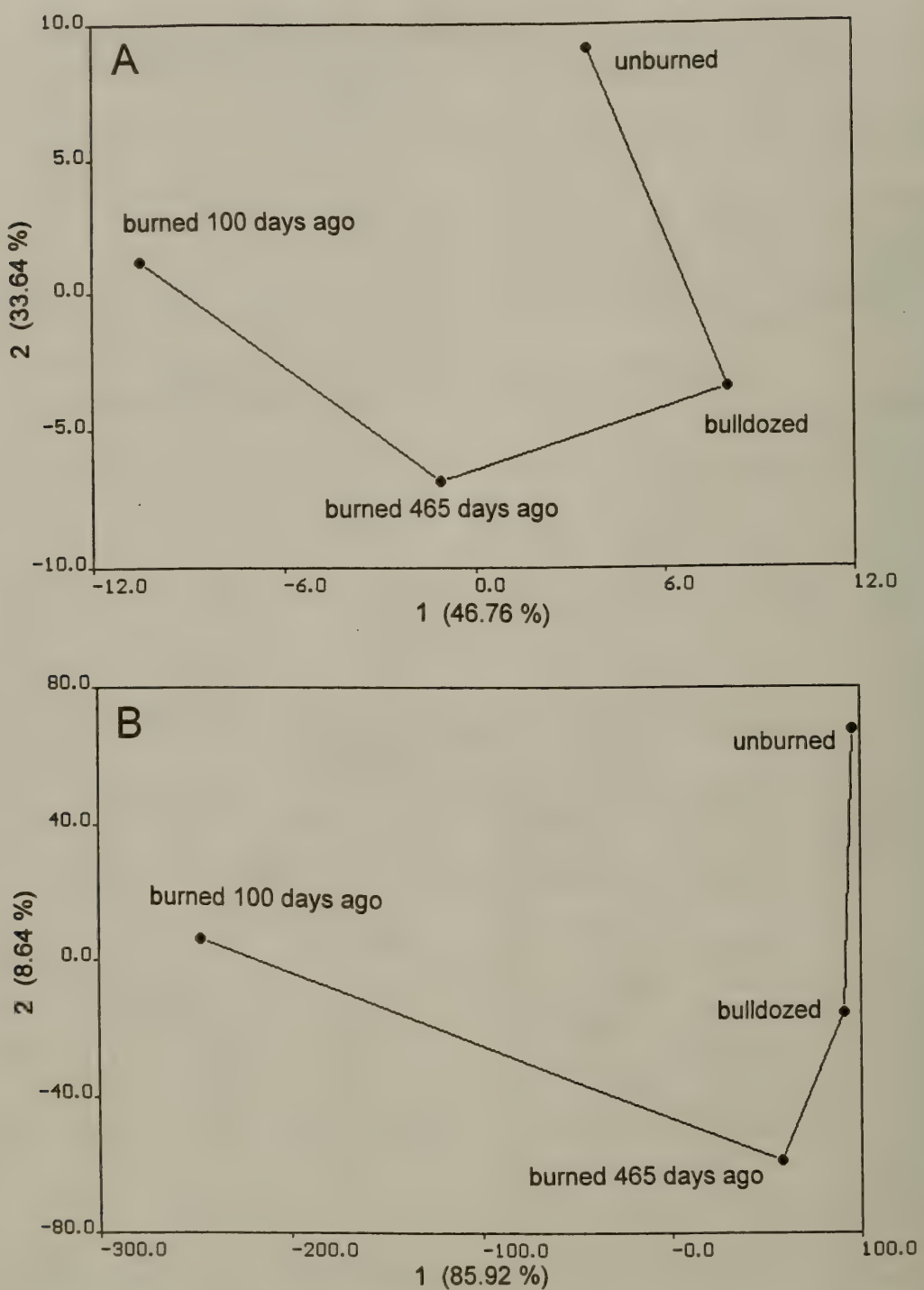

FIGURE 2. Plots of four alvar woodland plant communities based on principal coordinate analysis of distance coefficients with nearest neighbours of each community joined by a straight line forming a minimum spanning tree. A, based on % frequency data. B, based on total cover data.

woodland community to unburned and bulldozed tracks probably relates to longer time available for species to move in from the surrounding woodland. The community that develops in the same year as a spring fire is evidently entirely dependent on the soil seed bank or surviving roots (Catling et al. 2001).

The undisturbed alvar woodland is very different from the disturbed woodland but community change over a very short time following disturbance may also account for substantial variation in the communities; in the present case up to 34% (second axis). The type of disturbance may also contribute to variation in community development, which in the present case is almost 20% (third axis). Not only does disturbance have a major impact on creation of new communities in alvar woodland, but in addition, the new communities may change very rapidly in early succession suggesting that maximum community diversity is achieved by disturbances that are nearly continuous in time on different parts of the alvar

TABLE 2. Squared correlations for 67 vascular plant species with more than 5 % cover in four different alvar woodland vascular plant communities indicating relative importance of each of three factors in correspondance analysis.

Species	Factor 1	Factor 2	Factor3
Abies balsamea (L.) Miller, Balsam Fir	0.467831	0.502587	0.029583
Agrostis hyemalis (Walter) B. S. P., Tickle Grass	0.007751	0.825557	0.166692
Aquilegia canadensis L., Wild Columbine	0.044937	0.526885	0.428178
Aralia nudicaulis L., Wild Sarsaparilla	0.420369	0.498285	0.081346
Arctostaphylos uva-ursi (L.) Spreng., Bearberry	0.412632	0.506172	0.081196
Aster ciliolatus Lindl., Ciliolate Aster	0.108706	0.522276	0.369019
Aster macrophyllus L., Large-leaved Aster	0.408420	0.243439	0.348140
Astragalus neglectus (Torr. & A. Gray) E. Sheld.	0.037240	0.958930	0.003830
Bromus kalmii A. Gray, Kalm's Brome	0.645291	0.031153	0.323556
Calystegia spithamaea (L.) Pursh ,	0.599407	0.297767	0.102826
Campanula rotundifolia L., Blue Bell	0.284006	0.576360	0.139633
Carex houghtoniana Torr. ex Dewey	0.050306	0.199753	0.749942
Carex bebbi (L. H. Bailey) Olney ex Fern.	0.056024	0.773362	0.170614
Carex castanea Wahlenb., Chestnut Sedge	0.758668	0.239484	0.001848
Carex eburnea Boott, Bristle-leaved Sedge	0.014493	0.799958	0.185548
Carex richardsonii R. Br., Richardson's Sedge	0.199354	0.491836	0.308810
Cerastium fontanum Baumg., Chickweed	0.110507	0.350475	0.539018
Chaenorrhinum minus (L.) Lange, Snapdragon	0.009731	0.971541	0.018728
Chrysanthemum leucanthemum L., Ox-eye Daisy	0.103101	0.456368	0.440532
Cirsium vulgare (Savi) Ten., Bull Thistle	0.077574	0.707023	0.215403
Cirsium arvense (L.) Scop., Canada Thistle	0.149842	0.826019	0.024139
Clinopodium vulgare L., Wild Basil	0.352700	0.105433	0.541867
Corydalis aurea Willd. ssp. *aurea*, Corydalis	0.757183	0.228239	0.014578
Cypripedium parviflorum var. *pubescens*	0.769190	0.015693	0.215118
Danthonia spicata (L.) P. Beauv. ex Roern.	0.402117	0.569357	0.028526
Dracocephalum parviflorum Nutt., Dragonhead	0.933955	0.065615	0.000429
Epilobium ciliatum Raf. ssp. *ciliatum*, Willow-herb	0.041559	0.263126	0.695314
Epipactis helleborine (L.) Crantz, Helleborine	0.467831	0.502587	0.029583
Erigeron sp., Fleabane	0.018426	0.479189	0.502386
Fragaria virginiana Miller ssp. *virginiana*	0.306534	0.421030	0.272436
Geranium bicknellii Britton, Bicknell's Crane's-bill	0.900205	0.089319	0.010476
Hieracium piloselloides Vill., King Devil	0.400123	0.107874	0.492003
Hypericum perforatum L., St. John's-wort	0.070520	0.609198	0.320283
Juniperus communis L., Common Juniper	0.362455	0.132165	0.505380
Maianthemum canadense Desf., Lily-of-the-valley	0.706006	0.255860	0.038134
Medicago lupulina L., Black Medick	0.333388	0.474720	0.191892
Minuartia michauxii (Fenzl) Farw., Sandwort	0.102398	0.465142	0.432461
Muhlenbergia glomerata (Willd.) Trin.	0.030957	0.222663	0.746380
Panicum acuminatum Sw. var. *acuminatum*	0.044580	0.266694	0.688725
Panicum flexile (Gattinger) Scribn.,	0.079371	0.320996	0.599633
Petasites frigidus (L.) Fr., Sweet-coltsfoot	0.196585	0.075124	0.728291
Poa compressa L., Canada Blue Grass	0.300130	0.596609	0.103261
Polygala senega L., Seneca-snakeroot	0.616169	0.077459	0.306372
Populus tremuloides Michx., Trembling Aspen	0.695221	0.260917	0.043862
Potentilla argentea L., Silvery Cinquefoil	0.110507	0.350475	0.539018
Prunella vulgaris L. ssp. *vulgaris*, Heal-all	0.759266	0.002282	0.238452
Pteridium aquilinum (L.) Kuhn var. *latiusculum*	0.657057	0.321026	0.021917
Rhamnus frangula L., Glossy Buckthorn	0.663266	0.336484	0.000250
Rhus radicans L. ssp. *negundo* (Greene) McNeill	0.882571	0.059608	0.057821
Rosa acicularis Lindl. ssp. *sayi*	0.624554	0.374235	0.001211
Rubus pubescens Raf., Dwarf Raspberry	0.364056	0.025027	0.610917
Scutellaria parvula Michx. var. *parvula*, Skullcap	0.624665	0.190108	0.185226
Senecio pauperculus Michx., Balsam Groundsel	0.627150	0.360957	0.011893
Sisyrinchium sp., Blue-eyed Grass	0.017440	0.981032	0.001528
Solidago juncea Aiton, Early Goldenrod	0.057777	0.151904	0.790319
Solidago nemoralis Aiton ssp. *nemoralis*	0.036156	0.440516	0.523328
Solidago canadensis L, Canada Goldenrod	0.201236	0.470151	0.328614
Symphoricarpos albus (L.) S. F. Blake, Snowberry	0.099023	0.576365	0.324611
Taraxacum officinale G. Weber, Dandelion	0.091847	0.260526	0.647627
Trichostema brachiatum L., False Pennyroyal	0.076734	0.549014	0.374252
Trifolium pratense L., Red Clover	0.028573	0.373976	0.597451
Trifolium hybridum L. ssp. *elegans*	0.020853	0.452093	0.527055
Verbascum thapsus L., Common Mullein	0.056447	0.467917	0.475636
Vicia cracca L., Tufted Vetch	0.598659	0.021414	0.379927
Viola adunca Sm, Hooked-spur Violet	0.677599	0.268722	0.053679
Viola nephrophylla Greene, Northern Bog Violet	0.784490	0.000178	0.215332
Waldsteinia fragarioides (Michx.) Tratt.	0.444189	0.532909	0.022902

landscape, with a time lapse ranging from weeks to hundreds of years (e.g., alvar woodland burned the current year, burned 2 years ago, burned 5 years ago, burned 25 years ago, etc.).

To have the early stages (such as 100 days) represented continuously, on a large scale, would quickly use up alvar woodland that took hundreds of years to develop. However, localized and small scale soil disturbances in small and isolated portions of alvar woodland could contribute to maintaining the early successional communities. Fires every 25 to 50 years would have the same effect but produce long lasting, and less rapidly changing, high diversity open areas of the kind described earlier from the Burnt Lands (Catling and Brownell 1998).

The species plot from correspondence analysis shows a relatively small number of species uniquely or strongly associated with the undisturbed alvar woodland compared to a relatively large number associated with disturbance more than a year earlier and a moderate number uniquely and strongly associated fire 100 days earlier. This is a generally well established pattern involving higher levels of diversity in intermediate successional stages. Comparison of Figures 1A and 1B suggests that the species strongly associated with unburned woodland include (in descending order of suggested association with corresponding number in the plot): (1) *Abies balsamea*, (5) *Arctostaphylos uva-ursi*, (67) *Waldsteinia fragarioides*, (48) *Rhamnus frangula*, and (14) *Carex eburnea*. Species associated with unburned woodland and bulldozed tracks are (24) *Cypripedium parviflorum* var. *pubescens*, (46) *Prunella vulgaris* and (9) *Bromus kalmii*. At the other end of the scale, species associated with alvar woodland burned 100 days earlier are (in descending order of importance): (10) *Calystegia spithamaea*, (65) *Viola* cf *adunca*, (44) *Populus tremuloides*, (35) *Maianthemum canadense*, (23) *Corydalis aurea*, (52) *Scutellaria parvula*, (31) *Geranium bicknellii* (26) *Dracocephalum parviflorum*, (49) *Rhus radicans* ssp. *negundo*, and (4) *Aralia nudicaulis*. Introduced species such as (63) *Verbascum thapsus* and (45) *Potentilla argentea* were uniquely associated with bulldozed tracks. Similar trends are seen in Table 2 with regard to the axes. For example, the most important species with regard to factor 1 in the correspondance analysis are *Dracocephalum parviflorum* and *Geranium bicknellii,* both very well developed in alvar woodland 100 days after a fire and evidently dominants of a very short-lived (one year or less) post-fire community (Appendix 1).

Based on current knowledge, removal of woody biomass leads to very distinct early successional communities (Catling et al. 2001, this paper) which are replaced relatively quickly by longer lasting and more slowly changing alvar scrublands or "successional alvar burns" (Catling and Brownell 1998). This stage has more composition in common with the mixed or conifer-dominated alvar woodland and is probably reached with increasing rapidity as more trees become established. It is a relatively long lasting and slowly changing community. The very different composition of the disturbed communities and their larger number of unique and strongly associated species suggests that disturbance in the form of biomass removal can contribute substantially to protection of biodiversity.

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APPENDIX 1. Percentage frequency and total cover (dm²) of vascular plants with more than 5 % frequency in four different stages of vegetation development in alvar woodland.

(1) unburned alvar woodland adjacent to the burned woodland and bulldozed tracks (using 100 quadrats with data collected in October 2000). (2) burned woodland 100 days after a severe fire (using 250 quadrats with data collected 1–7 October 1999); (3) burned woodland a year later and approx. 465 days after the fire (using 150 quadrats of which 140 were in essentially the same positions as for 1 with data collected in October 2000); and (4) non-driven portions of bulldozed tracks through unburned alvar woodland 465 days after the bulldozing which was done in connection with the fire control (using 100 quadrats with data collected in October 2000). Based on data from the Burnt Lands near Almonte, eastern Ontario.

No.	Species	Unburned Frequency (%)	Burned Frequency (%) 1999	Burned Frequency (%) 2000	Bulldozed Frequency (%)	Unburned Cover (dm²)	Burned Cover (dm²) 1999	Burned Cover (dm²) 2000	Bulldozed Cover (dm²)
1	*Abies balsamea* (L.), Miller, Balsam Fir	30	–	–	–	350.5	–	–	–
2	*Agrostis hyemalis* (Walter) B. S. P., Tickle Grass		1.2	5.3	11		1.3	16	27
3	*Aquilegia canadensis* L. Wild Columbine	5	3	8.7	40	7.5	20.6	19	61.5
4	*Aralia nudicaulis* L., Wild Sarsaparilla	2	9.2	0.7	0.7	20 2	4.1	4	4
5	*Arctostaphylos uva-ursi* (L.) Spreng., Common Bearberry	16	0.8	3.3	–	140.8	0.6	2.5	–
6	*Aster ciliolatus* Lindl. Ciliolate Aster	5	5.6	11.3	19	3.5	23.6	93.6	56.7
7	*Aster macrophyllus* L., Large-leaved Aster	3	10.8	4	9	22	140.9	129	64
8	*Astragalus neglectus* (Torr. & A. Gray) E. Sheld., Neglected Milkvetch	1	0.4	12.7	16	0.5	3	145	49.5
9	*Bromus kalmii* A. Gray, Kalm's Brome	3	–	0.7	8	2	–	0.5	4.7
10	*Calystegia spithamaea* (L.) Pursh, Low Bindweed	–	5.2	–	–	–	3.1	–	–
11	*Campanula rotundifolia* L. Blue Bells of Scotland	5	8.8	15.3	19	4.5	14.9	42.7	24.3
12	*Carex bebbi* (L. H. Bailey) Olney ex Fern., Bebb's Sedge	–	–	12.7	1	–	–	116	3
13	*Carex castanea* Wahlenb., Chestnut Sedge	–	0.1	2	5	–	0.5	9	1
14	*Carex eburnea* Boott, Bristle-leaved Sedge	50	–	12	32	561		35.5	191.6
15	*Carex houghtoniana* Torr. ex Dewey, Houghton's Sedge	–	0.4	5.3	4	–	3	7.6	26
16	*Carex richardsonii* R. Br., Richardson's Sedge	18	4	56.7	50	67	1.8	211.8 1	21
17	*Cerastium fontanum* Baumg., Larger Mouse-ear Chickweed	–	–	–	12	–	–	–	9.9
18	*Chaenorrhinum minus* (L.), Lange, Dwarf Snapdragon	–	–	5.3	6	–	–	12	5.8
19	*Chrysanthemum leucanthemum* L., Ox-eye Daisy	–	–	1.3	12	–	–	2.5	41.4
20	*Cirsium arvense* (L.) Scop.. Canada Thistle	–	–	2	6	–	–	5.4	27
21	*Cirsium vulgare* (Savi) Ten., Bull Thistle	–	1.6	4	5	–	18	49	85.5
22	*Clinopodium vulgare* L., Wild Basil	3	0.4	–	14	3	5	–	14.7
23	*Corydalis aurea*, Willd. ssp. *aurea*, Golden Corydalis		33.6	11.3			262.9	239.3	
24	*Cypripedium parviflorum* var. *pubescens*, Ladys-slipper	3	–	–	5	3.5	–	–	6
25	*Danthonia spicata* (L.) P. Beauv. ex Roern. & Schult., Poverty Oat Grass	8	1.6	18.7	32	11.5	1	125.5	161.2

continued

APPENDIX 1. *continued*

No.	Species	Unburned Frequency (%)	Burned Frequency (%) 1999	Burned Frequency (%) 2000	Bulldozed Frequency (%)	Unburned Cover (dm^2)	Burned Cover (dm^2) 1999	Burned Cover (dm^2) 2000	Bulldozed Cover (dm^2)
26	*Dracocephalum parviflorum* Nutt., American Dragonhead	–	8.8	6.6	3	–	46.2	98.5	16.5
27	*Epilobium ciliatum* Raf. ssp. *ciliatum,* Ciliate Willow-herb	–	–	6	1	–	–	12.5	1
28	*Epipactis helleborine* (L.) Crantz, Common Helleborine	13	–	–	–	19.5			
29	*Erigeron* sp., Fleabane	–	–	17.3	7	–	–	181	15.8
30	*Fragaria virginiana* Miller ssp. *virginiana,* Scarlet Strawberry	7	1.2	12.7	41	5.3	1.9	31.2	104.6
31	*Geranium bicknellii* Britton, Bicknell's Crane's-bill	–	70.4	56	11	–	1328.2	385.5	32.5
32	*Hieracium piloselloides* Vill., Glaucous King Devil	9	6.4	11.3	28	11.3	15.2	16	43.2
33	*Hypericum perforatum* L., Common St. John's-wort	–	0.8	8	31	–	0.5	11	139
34	*Juniperus communis* L., Common Juniper	1	–	–	5	60	–	–	3
35	*Maianthemum canadense* Desf., Wild Lily-of-the-valley	–	6	1.3	–	–	3.9	2.2	–
36	*Medicago lupulina* L., Black Medick	–	7.2	10.7	16	–	63.4	35.5	99.7
37	*Minuartia michauxii* (Fenzl) Farw., Rock Sandwort	–	–	0.7	6	–	–	1	14
38	*Muhlenbergia glomerata* (Willd.) Trin., Glomerate Satin Grass	1	0.4	22	4	0.5	0.5	118.9	3.3
39	*Panicum acuminatum* Sw. var. *acuminatum,* Acuminate Panic Grass	4	5.6	8	19	4.5	7.6	37.2	42.1
40	*Panicum flexile* (Gattinger) Scribn.	–	1.6	20.7	6	–	1.8	87.2	13
41	*Petasites frigidus* (L.) Fr., Palmate-leaf Sweet-coltsfoot	–	2.8	17.3	–	–	25.1	263.5	–
42	*Poa compressa* L., Canada Blue Grass	1	–	2.7	6	0.5	–	9	5.5
43	*Polygala senega* L., Seneca-snakeroot	6	–	2.7	18	5	–	2	11.3
44	*Populus tremuloides* Michx., Trembling Aspen	–	72.4	14	–	–	2363.6	39	–
45	*Potentilla argentea* L., Silvery Cinquefoil	–	–	–	6	–	–	–	15.6
46	*Prunella vulgaris* L. ssp. *vulgaris,* Common Heal-all	9	0.4	1.3	17	13.5	0.1	3	38.3
47	*Pteridium aquilinum* (L.) Kuhn var. *latiusculum* (Desv.) Underw. ex A. Heller, Eastern Bracken-fern	3	13.2	7.3	5	20.5	403.1	194	24
48	*Rhamnus frangula* L., Glossy Buckthorn	23	0.4	2	11	15.5	1.2	4	8.8
49	*Rhus radicans* L. ssp. *negundo* (Greene) McNeill, Poison-ivy	–	13.6	8	7	–	26.5	22.5	10.7
50	*Rosa acicularis* Lindl. ssp. *sayi* (Schwein.) W. Lewis, Prickly Rose	4	12	9.3	5	3	62.2	40	10.7
51	*Rubus pubescens* Raf., Dwarf Raspberry	–	3.6	12	–	–	8.4	79.1	–
52	*Scutellaria parvula* Michx. var. *parvula,* Small Skullcap	–	6.4	0.7	2	–	0.1	0.5	3.5

continued

APPENDIX 1. *continued*

No.	Species	Unburned Frequency (%)	Burned Frequency (%) 1999	Burned Frequency (%) 2000	Bulldozed Frequency (%)	Unburned Cover (dm^2)	Burned Cover (dm^2) 1999	Burned Cover (dm^2) 2000	Bulldozed Cover (dm^2)
53	*Senecio pauperculus* Michx., Balsam Groundsel	7	2.2	12.7	20	13.5	20.8	108.5	34.3
54	*Sisyrinchium* sp., Blue-eyed Grass	–	–	4.7	6	–	–	7.1	7
55	*Solidago canadensis* L., Canada Goldenrod	–	–	18.7	–	–	–	35.2	–
56	*Solidago juncea* Aiton, Early Goldenrod	–	0.8	1.3	8	–	2.3	11	39.8
57	*Solidago nemoralis* Aiton ssp. *nemoralis*, Gray Goldenrod	–	2.4	3.3	6	–	5.7	9.5	7.5
58	*Symphoricarpos albus* (L.) S. F. Blake, Snowberry	9	16.4	4.7	4	74	60.3	25.3	66.8
59	*Taraxacum officinale* G. Weber, Common Dandelion	2	6.4	54.7	16	1	20.8	103.6	24.6
60	*Trichostema brachiatum* L., False Pennyroyal	–	0.4	3.3	16	–	5	7.9	63.5
61	*Trioflium hybridum* L. ssp. *elegans* (Savi) Asch. & Graebn., Alsike Clover	–	–	47.3	14	–	–	359.7	83
62	*Trifolium pratense* L., Red Clover	–	–	5.3	2	–	–	14.8	5
63	*Verbascum thapsus* L., Common Mullein	–	3.2	8	50	–	15.4	55.5	578.1
64	*Vicia cracca* L., Tufted Vetch	–	2.4	5.3	1	–	4	10	0.5
65	*Viola adunca* Sm, Hooked-spur Violet	–	6.4	1	–	–	5.8	0.7	–
66	*Viola nephrophylla* Greene, Northern Bog Violet	16	0.8	20.7	20	12	0.6	26.5	25.9
67	*Waldsteinia fragarioides* (Michx.) Tratt., Barren Strawberry	61	7.6	9.3	12	422.2	11.9	62.5	36

Cooper's Hawks, *Accipiter cooperii,* Successfully Nest at High Densities in the Northern Great Plains

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Cooper's Hawk (*Accipiter cooperii*) has been classified as a species of special concern in most northern Great Plains states and provinces, mainly because of sparse data and poor understanding of its demography in the region. We measured the reproductive success and nesting density of Cooper's Hawks in the Souris River basin of north-central North Dakota during 1994–1996 and 1998–2000. Eleven of 14 (79%) nest areas located in 1986–87 were reoccupied when first checked during our study, and 10 of 12 (83%) nest areas occupied in 1994 were reoccupied in 2000, suggesting a stable population. Reproductive success (69% nest success and 2.0 large young/occupied nest, $n = 96$) was comparable to that reported for other regions. Nest success differed among three woodland types studied ($P = 0.034$). On two intensively searched areas, Cooper's Hawks were the most common nesting falconiform observed; nesting densities were one occupied nest/292 ha and one occupied nest/395 ha, among the highest reported for the species. Our data suggest that the Cooper's Hawk may be a common breeding species wherever deciduous woodlands are an important part (>10%) of northern Great Plains landscapes.

Key Words: Cooper's Hawk, *Accipiter cooperii,* nesting density, reproductive success, North Dakota, Great Plains

The mostly treeless Great Plains of North America provide the primary breeding habitat for many grassland-dependent bird species (Knopf 1996), but little habitat for many woodland species such as *Accipiter* hawks. For example, breeding Cooper's Hawks (*Accipiter cooperii*) have been thought to be rare in the western Dakotas (Stewart 1975:90; South Dakota Ornithologists Union 1991:74) and in southeastern Alberta (Semenchuk 1992:83). Indeed, this hawk has been regarded as a species of special concern in most northern Great Plains states and provinces because of perceived rarity and/or insufficient data on its population status and breeding biology (Anonymous 1991; Rosenfield et al. 1991). Increases in woodland habitat across the region during the mid- to late 1900s have influenced the abundance and distribution of several raptor species (Houston and Bechard 1983; Murphy 1993; Sargeant et al. 1993), and may have also influenced the Cooper's Hawk, e.g., breeding by the hawk now is confirmed or suspected in much of southern Saskatchewan (Smith 1996:103). In eastern North America, the Cooper's Hawk is classified as an area-sensitive, forest-interior species (reviewed in Grant and Berkey 1999). Recent data suggest a more flexible nesting habit, possibly enabling the hawk to nest successfully in what might appear to be marginally suitable locales (e.g., Rosenfield et al. 1995; Boal and Mannan 1998). To address geographic gaps in knowledge of the species' breeding status, we measured breeding density and reproductive success of Cooper's Hawks in several woodland types characteristic of the northern Great Plains.

Study Area and Methods

We studied Cooper's Hawks across the Souris River basin (48°40′ N, 101°25′ W) of north-central North Dakota. The Souris River forms a 110-km loop extending from Canada into North Dakota (Figure 1). During 1994–1995 and 1998–2000, we located nests of Cooper's Hawks along the western half of this riverine loop, including the Des Lacs River and intermittent tributaries ("coulees") of both rivers (Figure 1). This area included parts of Des Lacs National Wildlife Refuge (NWR) and Upper Souris NWR in Ward, Burke, and Renville counties, and privately-owned woodlands in Ward and southwestern McHenry counties. Woodlands occurred mainly within river floodplains and on north- and east-facing slopes (5–25°) of coulees, and were dominated by Green Ash (*Fraxinus pennsylvanica*) and American Elm (*Ulmus americana*). We defined woodlands within floodplains as floodplain woodlands, and those in adjacent coulees as coulee woodlands. Both woodland types were narrow (< 0.2 km wide) and linear. The area within 1 km of the Des Lacs and Souris rivers was composed of approximately 14% woodland, 35% grassland (native prairie and introduced grasses), and 31% cropland. Palustrine wetlands,

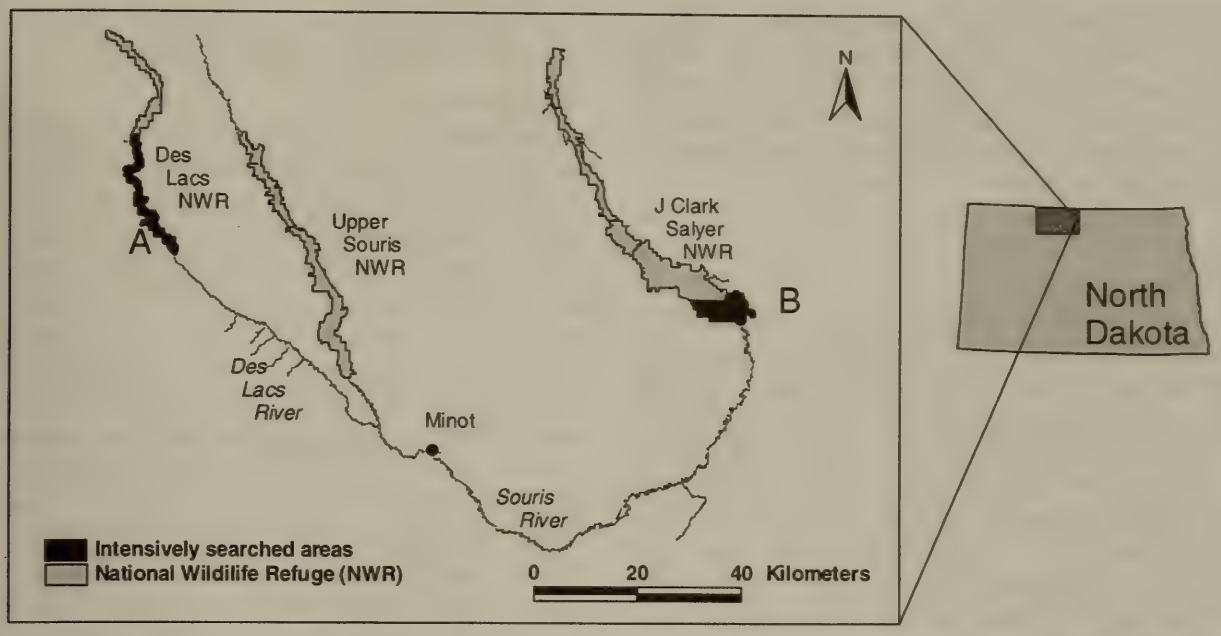

FIGURE 1. Cooper's Hawk study area in the Souris River basin of north-central North Dakota during 1994–1996 and 1998–2000, and two intensive study areas: A = 1998 intensive study area (3951 ha), containing 15 nest areas (10 occupied in 1998); and B = 1996 intensive study area (5263 ha), containing 18 nest areas.

open water, and rural towns and cities each composed < 10% of this riverine landscape.

During 1996 and 1998–2000, we located nests of Cooper's Hawks along the eastern half of the Souris River loop in North Dakota, on the southeastern third of J. Clark Salyer NWR in McHenry County (Figure 1). Floodplain woodland along the Souris River at J. Clark Salyer NWR was dominated by Green Ash and American Elm and was interspersed with sedge (*Carex* spp.)/grass (Gramineae) meadows. Uplands at J. Clark Salyer NWR were sandy, rolling hills with plant communities composed of 58% native prairie and 42% broadly scattered woodlands dominated by Quaking Aspen (*Populus tremuloides*), Bur Oak (*Quercus macrocarpa*), and Balsam Poplar (*P. balsamifera*). We defined these as sandhill woodlands. Climate of the study area was semiarid to subhumid continental with annual precipitation averaging about 42 cm (U.S. Fish and Wildlife Service, unpublished data).

Reproductive success

We located Cooper's Hawk nests during late April through June by searching woodlands throughout the study area on foot, including 14 nest areas recorded during 1986–1987 (G. Berkey and R. Martin, unpublished breeding bird atlas for Ward County; U.S. Fish and Wildlife Service, unpublished data). Because woodlands on our study area were either linear (coulee and floodplain woodlands) or in discrete groves (sandhill woodlands), we could scan all trees for stick nests by slowly walking transects through each woodland. As an aid in detecting nesting hawks, we broadcast a Cooper's Hawk alarm call every 10–20 min from a hand-held cassette player (Rosenfield et. al. 1985). A nest was considered occupied if eggs were laid, and successful if it produced at least one large nestling (≥ 23 d old [Steenhof 1987]). We defined a nest area as the area within 0.4 km of the original nest found. A nest area was considered reoccupied if a new nest was found within 0.4 km of where nesting had occurred at least six years previous (Rosenfield et al. 1995).

Nesting density

We measured Cooper's Hawk nesting density by selecting two intensive search areas where we had no prior knowledge of the hawk's breeding abundance other than observations of two nest areas on each search area. The two intensive search areas were selected because they afforded ready legal access and an arbitrary boundary (e.g., refuge fences) to confine our search. Also, a basic inventory of breeding raptors was among the top priority information needs on area NWRs. Although woodland types on the two intensive search areas were representative of those available on the study area, we acknowledge that nesting densities may not have been uniform across the study area. In 1996, we searched a 5263-ha area in the sandhill woodlands at J. Clark Salyer NWR (Figure 1). We did not include floodplain woodlands in our intensive search area at J. Clark Salyer NWR because flooding precluded access to most of this area through late spring, and we were not confident all nests in the multi-storied canopy of floodplain woodlands would be detected after leaf-out. In 1998, we searched a 3951-ha area on Des Lacs NWR (Figure 1). We measured the distance between Cooper's Hawk nests on aerial photographs

(1:7920, 1:15840) to determine nearest-neighbor nest distance. While on intensive search areas during spring and summer, we also recorded locations of occupied nests of other diurnal raptor species to assess abundance of Cooper's Hawks relative to other breeding raptors.

Results

Reproductive success

Cooper's Hawks returned to the study area in mid-April, and most females initiated egg-laying in mid-May (mean initiation date based on backdating from estimated nestling ages = 16 May, SE = 0.8 d, $n = 57$). We identified 56 Cooper's Hawk nest areas in the study area during 1994–1996 and 1998–2000. Eleven of 14 (79%) nest areas occupied in 1986–1987 were reoccupied when first checked in 1994–1995, and 10 of 12 (83%) nest areas occupied in 1994 were reoccupied in 2000. Reproductive success was recorded for one year only at each of 31 nest areas, for two years at 15 nest areas, for three years at six nest areas, and for four years at four nest areas. Cooper's Hawks produced an average of 2.0 large young/occupied nest and more than two-thirds of nests were successful (Table 1). However, Cooper's Hawks were less successful when nesting in coulee woodlands compared to sandhill woodlands ($\chi^2 = 6.783$, df = 2, $P = 0.034$; Figure 2). Including one pair that successfully renested after a failed nesting attempt, 15 of 30 (50%) nest failures occurred during the egg stage (mid-May through mid-June), five (17%) during the nestling stage, and timing of 10 failures (33%) was unknown. Shell fragments found at seven nests depredated during incubation were consistent with shell fragments found at duck nests depredated by Raccoons (*Procyon lotor*; Sargeant et al. 1998). Two failed nests contained eggs with small (1–1.5 cm) punctures attributed to avian predators, but the eggs may have been destroyed after nest abandonment. One nest failure was attributed to nestling predation by a Great Horned Owl (*Bubo virginianus*), and a second nest failed during incubation when the female was killed on the nest, probably by an avian predator.

Nesting density

Ten nests were found on the intensive search area at Des Lacs NWR in 1998, yielding a nesting density of one occupied nest/395 ha. Eighteen nests were found on the intensive search area at J. Clark Salyer NWR in 1996, yielding a nesting density of one occupied nest/292 ha. Nearest neighbor distance between nests averaged 2.1 km on Des Lacs NWR (range 1.3–3.2 km) and 1.5 km on J. Clark Salyer NWR (range 1.0-2.3 km). Cooper's Hawks were the most abundant nesting falconiform we observed on intensive search areas (Table 2). Northern Harriers (*Circus cyaneus*) may have been nearly as common at Des Lacs NWR (at least one occupied nest/439 ha), but we were unable to locate all Harrier nests because our survey methodology was better suited for tree-nesting raptors. We were confident that the Harrier was an uncommon nesting raptor (only one or two nesting pairs) in the sandhill woodlands at J. Clark Salyer NWR.

Discussion

Reproductive success

Reproductive success in our study (2.0 young/occupied nest and 69% nest success) was in the middle of ranges reported for other regions (1.6–2.8 and 53–85%), as summarized by Rosenfield and Bielefeldt (1993). Our reproductive success data, like those from a prairie-parkland area in northwestern North Dakota (2.4 young/occupied nest [Murphy 1993]), suggest that Cooper's Hawk reproductive success in North Dakota is comparable to that of conspecifics in other regions. Additionally, observed nest area reoccupancy of 79% and 83% across six to nine years suggests a relatively stable population (Rosenfield et al. 1995).

Differences in woodland configuration may explain differences in nest success among the three woodland types we studied. Cooper's Hawk nest success in coulee woodlands may have been lower

TABLE 1. Cooper's Hawk reproductive success in north-central North Dakota by woodland type and for all nests combined, 1994–1996 and 1998–2000. Numbers presented are mean ± SE (number of nests).

	Woodland type			
Reproductive measure	Coulee	Floodplain[a]	Sandhill	All nests[b]
Mean clutch size	3.8 ± 0.2 (5)	2.0 ± 0.0 (1)	3.4 ± 0.2 (18)	3.5 ± 0.2 (28)
Mean number of large young/occupied nest[c]	1.6 ± 0.2 (44)	2.4 ± 0.4 (18)	2.4 ± 0.2 (28)	2.0 ± 0.2 (96)
Mean number of large young/successful nest[c]	2.8 ± 0.2 (25)	3.3 ± 0.2 (13)	2.8 ± 0.2 (24)	3.0 ± 0.1 (66)
% Nest success	57 ± 7.6 (44)	72 ± 10.9 (18)	86 ± 6.7 (28)	69 ± 4.8 (96)

[a]Includes one failed nesting attempt that was followed by successful renesting.

[b]Includes one nest in a tree planting (4 year), and two nests in urban parks (1 year each).

[c]Includes two nests classified as successful when young were 16- to 18-days old, because subsequent nest visits were not made.

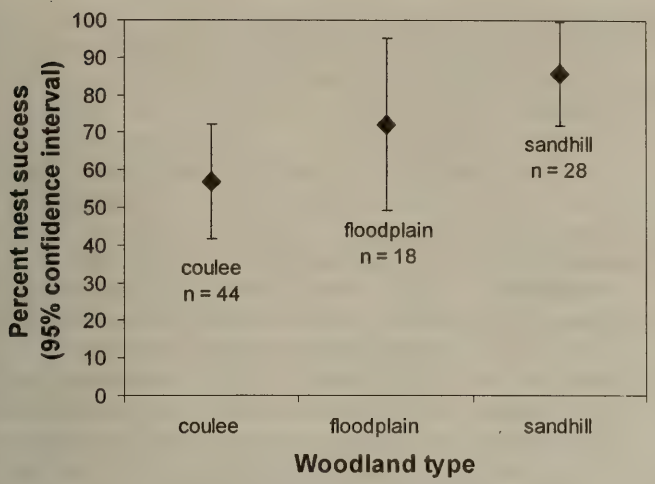

FIGURE 2. Cooper's Hawk reproductive success in three woodland habitat types in north-central North Dakota, 1994–1996 and 1998–2000.

than in other woodland types because the narrow coulee woodlands act as travel corridors for predators. Vander Haegen and DeGraaf (1996) found that artificial nests in narrow riparian buffer strips (20–40 m and 60–80 m wide) were more likely to be depredated than those in more extensive riparian forests (continuous forest extending > 400 m from the river). In our study, Cooper's Hawks nested most successfully in sandhill woodlands where predators (e.g., Raccoons) may have been less common and less able to locate nests among the widely scattered patches of woodland. Floodplain woodlands, although somewhat narrow like coulee woodlands, were surrounded by about twice as much woodland cover as were coulee woodlands (Nenneman et al. unpublished data), which may explain the intermediate nest success we observed in the floodplain.

Nesting density

Nesting densities in this study (one occupied nest/292–395 ha) match the highest densities reported for the species (one occupied nest/ 272–437 ha), in rural and urban Wisconsin (Rosenfield et al. 1991, 1995) and urban Arizona (Boal and Mannan 1998). Nesting densities in other parts of the northern Great Plains have been much lower: one occupied nest/1918 ha for mixed deciduous-coniferous woodlands of the Little Missouri River badlands in southwestern North Dakota (point estimate, 1978 stratified random sampling [Postovit 1979]), and one occupied nest/2174 ha for a prairie-parkland refuge in northwestern North Dakota, where woodland cover comprised only 2% of the area (Murphy 1993). Reynolds and Wight (1978) reported a nesting density of one occupied nest/1857 ha in contiguous coniferous forest in Oregon. Results of our study (sandhill woodlands at J. Clark Salyer NWR) and Rosenfield et al. (1995) suggest that Cooper's Hawks may reach highest nesting densities where woodlands make up roughly 40% of the landscape.

Nesting densities, reproductive success, and nest area reoccupancy observed in our study suggest Cooper's Hawks can maintain viable breeding populations in at least some contemporary woodlands of the northern Great Plains. Cooper's Hawks likely are increasing in the region because woodland cover has expanded since the early 1900s due to fire suppression, extirpation of bison, and planting of tree shelterbelts (Sargeant et al. 1993). For example, both intensive search areas in our study were nearly devoid of trees and presumably nesting Cooper's Hawks only 90–130 years ago (U. S. Fish and Wildlife Service, unpublished data). Relative to other regions, Cooper's Hawk nesting habitats in North Dakota differ structurally and are fragmented (Nenneman et al., unpublished data). Cooper's Hawks also are nesting in other newly available habitats in the state, such as tree shelterbelts at isolated farmsteads (R. Murphy, unpublished data). Houston and Bechard (1983) indicated that Red-tailed Hawks were limited in the prairie of southern Saskatchewan by lack of trees for nesting, but have become abundant since settlement in the late 1800s as woodland cover has increased. Our findings suggest that Cooper's Hawks in North Dakota had been similarly limited by the lack of trees for nesting, rather than by food resources, and have increased in abundance with increased woodland cover. Cooper's Hawks are flexible in their selection of nesting habitat, and readily nest in woodlands available in North Dakota. Resource personnel should be aware that this species likely is a significant component of

TABLE 2. Nesting densities of Cooper's Hawks relative to other diurnal raptor species on 5263- and 3951-ha intensive study areas at J. Clark Salyer NWR and Des Lacs NWR in North Dakota, 1996 and 1998.

Species	Density as ha/occupied nest (*n*)	
	J. Clark Salyer NWR	Des Lacs NWR
Cooper's Hawk, *Accipiter cooperii*	292 (18)	395 (10)
Red-tailed Hawk, *Buteo jamaicensis*	478 (11)	659 (6)
Swainson's Hawk, *B. swainsoni*	—[a] (0)	659 (6)

[a]None observed.

breeding raptor communities in areas of the northern Great Plains where deciduous woodlands are an important (> 10%) landscape component.

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The Forests of Prince Edward Island: A Classification and Ordination Using Multivariate Methods

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In 1991 data were collected on the ground flora in 1200 4 m^2 plots at 240 randomly selected forest sites on Prince Edward Island. The nearby trees and shrubs, and attributes of the surrounding forest stand were also recorded and soil samples were collected for analysis. Additional topographic, historical and soil data for each sampling point were obtained from maps and a 1935 aerial photographic survey. 1127 of the plots were subjected to multivariate analysis (a TWINSPAN classification and a DECORANA ordination). On the basis of their ground flora composition, TWINSPAN divided the plots into eleven ground flora community-types, which after further comparative analysis of their tree canopies, stand properties and environmental factors, were assigned to five forest-types, each characterised by particular tree species and soil drainage properties: (1) a wet species-rich woodland, (2) upland hardwood forest, (3) Black Spruce forest, (4) old field White Spruce woods, and (5) disturbed, mainly conifer-dominated, forest. The first three were considered to be heavily modified descendants of pre-settlement forest-types, while the two latter appeared to be largely the products of successional processes resulting from human disturbance and forest clearance. The ordination indicated that the most important factors responsible for the ground flora communities and forest-types on Prince Edward Island are soil drainage and human-associated disturbance.

Key Words: forest ground flora, forest classification, forest ordination, Prince Edward Island, TWINSPAN, DECORANA.

Prince Edward Island, comprising 5750 km^2, is the most agricultural and least forested of Canada's provinces. Lying within the so-called boreal-broadleaf ecotone (Scott 1995), it contains both deciduous hardwood forest, and tree species and communities characteristic of the more northerly boreal coniferous forest (Erskine 1960). Since the beginning of European settlement in 1720, and especially in the nineteenth century, its forests have been subjected to large-scale clearance such that by 1935 only 32% of its area was still under forest (Glen 1997), though by 1990 this area had increased to 49% (Anonymous 1992). However, the composition of its forests, either past or present, has never been studied in detail, with no comprehensive field-based study ever having been carried out. Those studies that have touched on the island, have either been general and brief, serving primarily to place its forests in the context of continental or regional forest-types (Halliday 1937; Rowe 1959; Loucks 1961), or, with forest description being peripheral to other aims, have been entirely qualitative and descriptive (Stilgenbauer 1929; Erskine 1960; MacDougall et al. 1988).

The study reported here rectifies this deficiency. It stems from an opportunity that arose in 1991 when the P.E.I. Forestry Division was planning the field work connected with a comprehensive inventory of the island's timber stock. Under the Division's conservation remit, it was decided to also collect information on the ground vegetation at each of the inventory's 1200 sampling points. Because of limitations in time and resources the ground flora assessment at each sampling point was confined to a single 4 m^2 circular plot, which had the potential for limiting the usefulness of the data collected. However, as will become evident from the results, even small plots, provided there are many of them, can yield valuable results.

Multivariate analytical methods were used to analyse the data, the aim being to classify and ordinate (i.e., arrange along gradients of changing plant community composition) the 1200 plots on the basis of their ground flora composition. The plot groups and gradients emerging could then be assessed in terms of environmental and other data recorded for each of the sampling points (either in the field or from maps); e.g., tree canopy properties, topographic attributes, soil properties, and management and historical factors. It was hoped that the analysis would lead to a precise documentation of the variation in the forests of the island and a greater understanding of the environmental factors determining the variation.

This study is unusual in that it aims to provide a comprehensive and precise description of the forests of an entire geographical entity. Also unusual in Canadian terms, is the fact that virtually all of this forest has been heavily affected by 150–270 years of human interference and disturbance. However, this does not mean that the study has no relevance outside

of Prince Edward Island: the island contains forests belonging to two continental forest types (the northern hardwoods and the boreal coniferous forest) and thus presents an opportunity for a detailed spatial analysis of these forest types in an area where they overlap. Also, at a regional level, the island's forests show affinities with the forests of adjacent parts of western Nova Scotia and southern and eastern New Brunswick (e.g., see Rowe 1959; Loucks 1961).

Methods

Field methods

The data on which this paper is based were collected as part of the 1990–1992 Prince Edward Island Forest Biomass Inventory, the field work for which was carried out by two teams of workers between June and September 1991 at 240 forest sites (Figure 1) selected prior to the field visits from maps using a fully randomised procedure. At each site, five sampling points were positioned (usually at 100 m intervals) along a cruise line whose compass-bearing and starting point had also been determined prior to the field visit and marked on aerial photographs (1:17,500) to aid location. To enhance inclusion of different forest types the cruise lines were chosen to run across map contour lines, where such occurred. The first sampling point was usually 100 m in from the wood edge. Alder scrub and clear-cut areas were to be excluded in the actual sampling and no sampling point was to be closer than 15 m to a boundary between two distinct forest types. With five sampling points at each of the 240 randomly chosen sites, a total of 1200 sampling points were assessed in the field inventory.

Site and forest attributes — At each of the 1200 sampling points the assessors recorded the slope (as a percentage) and the aspect (in eight directional classes), and the following standard forest inventory parameters based on a subjective impression of the general area around the sampling point (see Haddon (1989) for a definition of the terms): (1) the forest type; i.e., whether predominantly hardwood (HH — >75% hardwood, HS — 50–75% hardwood) or softwood (SS — >75% softwood, SH — 50–75% softwood); (2) the broad age class of the trees (regeneration, immature, mature, overmature, uneven-aged); (3) the stocking class of the trees (as four quartile percentage classes); (4) where evident, the origin and management history of the stand (i.e., swampy, bog, burn, partial cut, thinning, clear-cut, plantation, old field, or a combination of these); and (5) evidence of damage due to logging, insect defoliation, disease and windfall.

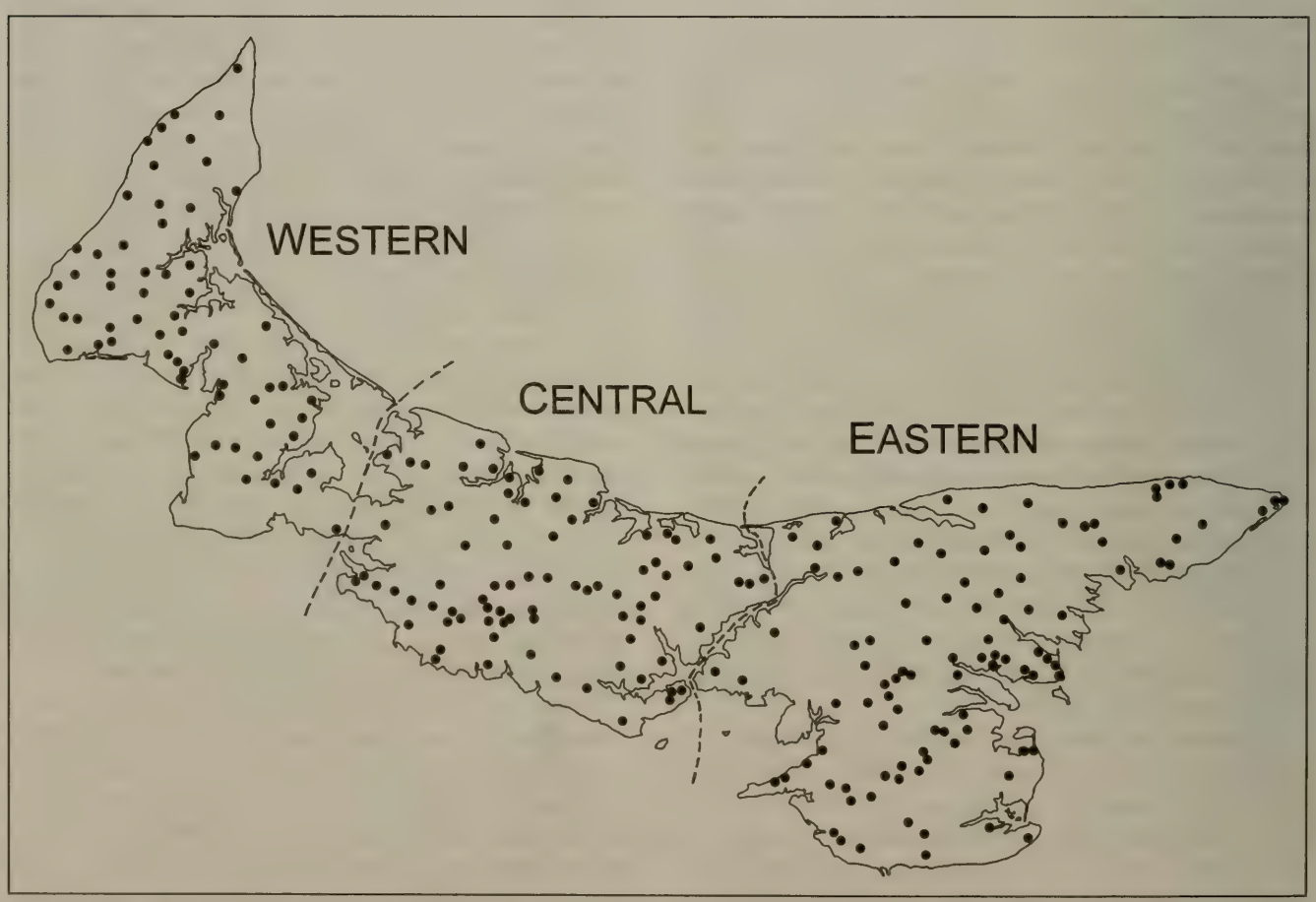

FIGURE 1. The 240 randomly-selected sampling sites assessed in the 1991 field survey — there were five 4 m^2 ground flora plots at each site. The three regions into which the island was divided for the purpose of this study are shown.

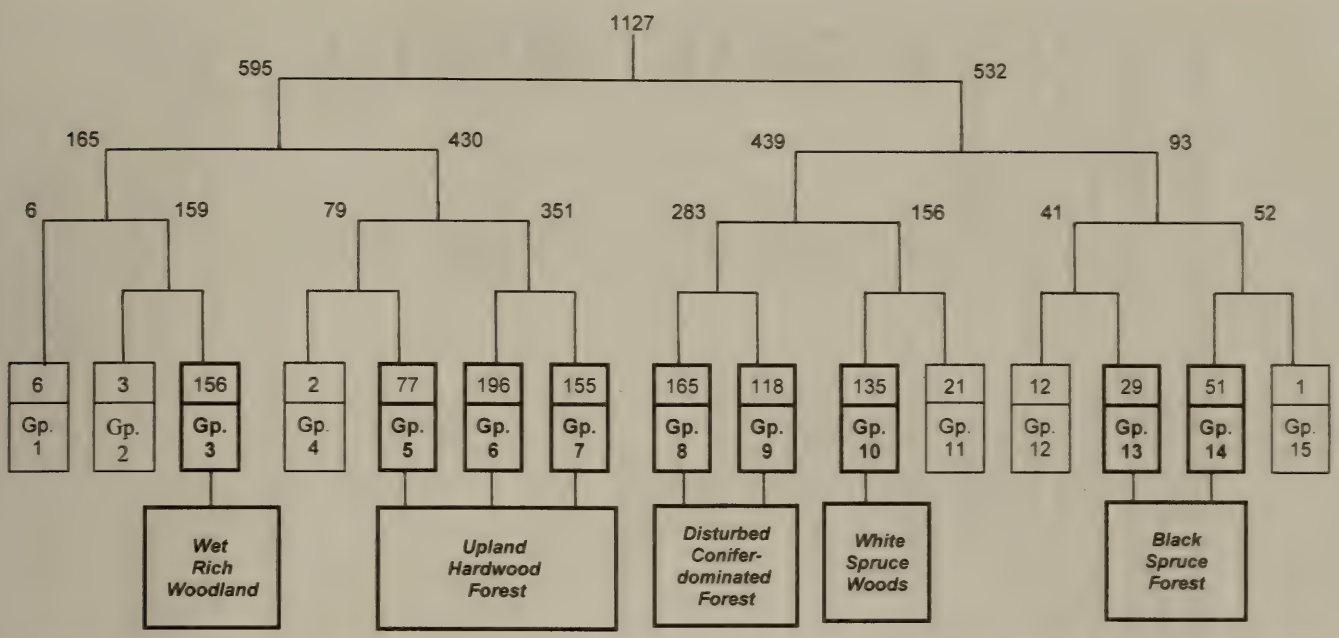

FIGURE 2. The TWINSPAN classification of 1127 ground flora plots: dendrogram showing the dichotomies leading to the fifteen plot groups generated at the fourth division level, and the five forest-types to which the plot groups were assigned. (The number of plots at each division is shown.)

Soil properties — A soil pit was dug near the sampling point and using standard soil survey techniques the following physical properties were determined in the field: soil drainage class (well-drained, moderately well-drained, imperfectly-drained, poorly-drained); rooting depth (cm); thickness of the A horizon (cm) (i.e. the distance from the start of the mineral soil under the H horizon, to the B horizon); root restriction factors (at all sampling points recorded as either due to a high water table or to soil compaction); and the texture of the B horizon. Soil samples were taken from both the H horizon (from just above the mineral soil) and from the B horizon (so as to include both the upper and lower part of the B). These were subsequently analysed for pH, total carbon and nitrogen, and available levels of phosphorus, potassium, calcium, magnesium and sulphur, as well as micronutrients.

The chemical analyses were carried out by the Prince Edward Island Department of Agriculture and Forestry Soil and Feed Testing Laboratory in Charlottetown using the following methods: the soil samples were oven-dried overnight at 40°C, ground in a soil crusher and passed through a 2 mm sieve. The pH was determined electrometrically on a 1:1 volume ratio of the ground and sieved soil and distilled water; total carbon and nitrogen were determined by combustion on a CHN analyser; available Ca, Mg, K, P and S were extracted using a Mehlich III extract at a 1:10 soil to extract ratio, shaken and filtered, and run on an Inductively Coupled Argon Plasma (ICAP) Spectrometer. For carbon and nitrogen, final values were expressed as percentage of oven-dried soil, for all of the other elements, as parts per million.

Vegetation assessment — At each sampling point the vegetation was assessed as three separate categories:

1. *Trees* (≥ 9 cm DBH, including standing dead trees) were assessed using a 'point sampling' technique (Watts 1983), which involved the use of a 'variable-radius plot' centred on the sampling point, with trees being selected for inclusion in the sample using a wedge prism of Basal Area Factor = 2 m^2. The species of each tree and its DBH to the nearest cm was recorded. From this data, the percentage contribution (to the nearest 10%) of each tree species to the total woody biomass in each variable-radius plot was calculated. Two trees, generally the largest broadleaf and conifer, were selected for measurement of height (using a clinometer), and age at breast height (using an increment borer).

2. *Small trees and woody shrubs* (≥ 1.3 m in height but < 9 cm DBH) were assessed within a 16 m^2 circular plot (radius 2.26 m) centred on the sampling point. For each plant, the species and vitality (i.e. whether living or dead) was recorded, as well as its DBH to the nearest cm.

3. *Ground flora* — all species of vascular ground plants including woody shrubs < 1.3 m in height (but excluding tree species); and selected species of mosses, liverworts and lichens were assessed within a circular 4 m^2 plot (radius 1.13 m), the centre of which, to avoid the effects of the trampling involved in the tree and shrub sampling, was moved 5 m onward from the sampling point along the bearing of the cruise line. Based on a visual impression of its cover-abundance, each species or other taxonomic category was given a percentage cover value to the nearest 10% with a minimum of 5%.

TABLE 1. The mean (± SE) of the percentage contribution of the principal tree species to the total tree biomass in the variable-radius plots of the TWINSPAN forest-types. Species presence at < 1% biomass is indicated by a dot (•). [The letters following each value refer to the Scheffé multiple comparison test — see footnote.]

	FOREST-TYPES (and corresponding TWINSPAN groups)						
TREE SPECEIS	Wet Rich Woodland (TSP Group 3)	Upland Hardwood Forest (TSP Groups 5 + 6 + 7)	Disturbed Conifer Forest (TSP Groups 8 + 9)	White Spruce Woods (TSP Group 10)	Black Spruce Forest (TSP Groups 13 + 14)	ONE-WAY ANOVA† F	p
CONIFERS:							
Picea mariana	3.8 (1.2) a b	• a b	10.1 (1.4) a b*	4.3 (1.5) a	53.1 (4.9) a*	124.0	0.0000
Picea rubens	• a b	• a b	7.1 (1.2) a b*	4.6 (1.2) a	17.3 (3.8) a*	25.5	0.0000
Picea glauca	18.0 (2.2) a b*	8.6 (0.92) a b c	16.7 (1.5) a c*	62.2 (3.4) a*	7.2 (2.3) a b	120.8	0.0000
Abies balsamea	13.5 (1.5) a	18.9 (1.2) a b*	24.9 (1.6) a*	8.4 (1.7) a b	6.9 (1.9) a b	17.2	0.0000
Larix laricina	7.3 (1.7) b*	• a b c	3.8 (0.69) a c*	3.7 (0.84) a	9.0 (2.1) a*	15.2	0.0000
Thuja occidentalis	7.1 (1.7) a*	• a	• a		• a	17.7	0.0000
TOTAL CONIFERS (%)	50.0	30.4	64.5	84.1	94.4		
BROAD-LEAVES:							
Acer rubrum	24.6 (2.4) a b*	33.3 (1.4) a*	19.0 (1.5) a c*	4.6 (1.1) a b c	2.5 (0.77) a b c	48.2	0.0000
Acer saccharum	1.7 (0.56) a	9.7 (0.89) a*	• a	• a		36.8	0.0000
Betula alleghaniensis	3.3 (0.84) a	5.6 (0.62) a*	1.4 (0.40) a	• a		14.7	0.0000
Betula papyrifera	5.6 (0.94) a	9.2 (0.74) a*	4.1 (0.60) a	3.6 (0.78) a	• a	14.2	0.0000
Fagus grandifolia		4.1 (0.58) a*	• a	• a		17.3	0.0000
Populus tremuloides	7.8 (1.6) a*	4.1 (0.65) a b	7.4 (1.1) b*	4.7 (1.2)	1.1 (1.0) a b	4.4	0.0015
Fraxinus americana	1.6 (0.75)	•				3.7	0.005
Ulmus americana	3.2 (1.1) a*	• a				11.8	0.0000
Alnus incana	4.8	•	1.9	1.2	•		
TOTAL BROAD-LEAVES (excluding *Alnus*) (%)	50.0	70.0	35.0	16.5	5.3		
NUMBER OF POINTS	156	428	283	135	80		

†One-way Anova: Scheffé test: means followed by a letter are significantly different ($p < 0.05$) from a mean with an asterisk: e.g.: 'a' is significantly different from 'a*'.

TABLE 2. The drainage classes of the TWINSPAN forest-types: (a) as determined from soil pits at the sampling points during the 1991 field survey; (b) based on the drainage class of the predominant soil series of the map polygon in which the sampling points were located, as determined from 1:10 000 soil series maps (MacDougall et al. 1988). For each forest-type the percentage of its sampling points in each drainage class is given.†

	FOREST-TYPES (and corresponding TWINSPAN groups)						
SOIL DRAINAGE CLASS	Wet Rich Woodland (TSP Group 3)	Upland Hardwood Forest (TSP Groups 5 + 6 + 7)	Disturbed Conifer Forest (TSP Groups 8 + 9)	White Spruce Woods (TSP Group 10)	Black Spruce Forest (TSP Groups 13 + 14)	All Points	χ^2 row sums
(a) SOIL PITS:							
Well-drained	**17.9 – *****	**88.6 + *****	56.2	**84.4 + ****	**15.0 – *****	63.8	**133.7**
Moderately well-drained	23.7	**9.6 – *****	**27.9 + *****	14.1	18.8	17.4	**36.9**
Imperfectly-drained	**16.0 + ****	**1.6 – *****	**13.8 + ****	**1.5 – ****	**26.3 + *****	8.6	**79.0**
Poorly-drained	**42.3 + *****	**0.23 – *****	**2.1 – *****	**0 – *****	**40.0 + *****	10.2	**316.1**
χ^2 column sums	**235.7**	**120.3**	**44.7**	**30.9**	**134.1**		
(b) SOIL SERIES MAPS:							
Rapidly-drained	**4.5 – *****	**10.7 – ***	**19.8 + ***	**29.6 + *****	16.3	14.9	**40.3**
Well-drained	**14.7 – *****	**72.0 + *****	**39.6 – ***	53.3	**8.8 – *****	48.2	**117.1**
Moderately well-drained	0.64	4.4	3.2	3.0	1.3	3.1	6.3
Imperfectly-drained	**19.9 + *****	**5.8 – ***	12.7	**4.4 – ***	**18.8 + ***	10.4	**33.2**
Poorly-drained	**60.3 + *****	**7.0 – *****	24.7	**9.6 –****	**55.0 + *****	23.2	**186.6**
χ^2 column sums	**156.5**	**114.3**	10.4	**35.4**	**67.0**		
NUMBER OF POINTS	156	428	283	135	80	1082	

†χ^2 tests of association: **soil pits**: total $\chi^2 = 565.9$ (d.f. = 12, $p < 0.001$); (Cramer's V = 0.417); **soil series**: total $\chi^2 = 383.1$ (d.f. = 16, $p < 0.001$); (Cramer's V = 0.297). The percentages for which the corresponding χ^2 values were statistically significant are printed in bold (d.f. = 1, * - $p < 0.05$; ** - $p < 0.01$; *** - $p < 0.001$). For such percentages a '+' or '–' indicates the nature of the association between the particular forest-type and drainage class. Column or row χ^2 sums printed in bold are significant at $p < 0.01$ (for rows, d.f. = 4; for columns, d.f. = 3 for soil pits, and 4 for soil series).

TABLE 3. The mean (± SE) of the pH and soil nutrient levels in the humus layer of the TWINSPAN forest-types (carbon and nitrogen are *total* values, all others are *available* values). (The letters following the values refer to the Scheffé multiple comparison test.†)

	FOREST-TYPES (and corresponding TWINSPAN groups)					ONE-WAY ANOVA†	
TREE SPECIES	Wet Rich Woodland (TSP Group 3)	Upland Hardwood Forest (TSP Groups 5 + 6 + 7)	Disturbed Conifer Forest (TSP Groups 8 + 9)	White Spruce Woods (TSP Group 10)	Black Spruce Forest (TSP Groups 13 + 14)	F	p
pH	5.4 (0.08) a*	4.3 (0.02) a b	4.1 (0.03) a b	4.2 (0.04) a b	3.9 (0.07) a b*	150	0.000
Carbon (%)	22.2 (1.2) a*	14.1 (0.50) a b*	22.4 (0.69) b c*	14.0 (0.86) a c d*	31.1 (1.4) a b c d	57.8	0.000
Nitrogen (%)	1.32 (0.10) a*	0.73 (0.04) a b*	1.01 (0.04) a b c*	0.64 (0.03) a c d*	1.01 (0.05) d	20.9	0.000
C / N ratio	17.0 (0.30) a*	19.5 (0.23) a b c*	23.1 (0.33) a b c	21.9 (1.4) a b	31.9 (1.3) a b*	56.9	0.000
Phosphorus (ppm)	112 (8.2) a*	182 (5.3) a b*	222 (9.7) a b c*	180 (10.2) a c	158 (13.1) c	19.3	0.000
Calcium (ppm)	5120 (296) a*	814 (50.8) a	1020 (65.1) a	645 (42.1) a	904 (177) a	211.0	0.000
Magnesium (ppm)	757 (114) a*	264 (37.9) a	348 (18.4) a	204 (15.6) a	432 (29.5) a	14.1	0.000
Sulphur (ppm)	74.8 (5.2) a*	39.1 (1.2) a b*	55.3 (3.2) a b	42.5 (4.9) a c*	68.2 (11.6) b c	16.3	0.000
NUMBER OF SAMPLES	143	418	279	128	79		

†ONE-WAY ANOVA: Scheffé test: means followed by a letter are significantly different ($p < 0.05$) from a mean with an asterisk: e.g.: 'a' is significantly different from 'a*'

For most plants, identification was carried out to the species level but for some difficult taxa only the genus was identified (i.e., *Amelanchier, Salix*), while for others, either the species or the genus, depending on the stage of development of the particular plant and the experience of the assessor (i.e., *Aster, Carex, Equisetum, Habenaria, Hieracium, Solidago, Cladina, Viola*). Frequently grasses were grouped under "grass" and most moss species under "moss" other than those to be identified specifically. (Vascular plant nomenclature follows Zinck (1998); moss nomenclature follows Ireland (1982). See Sobey (1993) for a complete listing of all of the species recorded in the inventory.)

All field data were fed directly at the site into a portable data collector (Digitech Memo MD-3) and later transferred to a PC computer database file (D-Base IV).

Map-derived data

Using ruler and compass the cruise lines and sampling points were precisely transferred from the aerial photographs used in the field visits to 1:50,000 Canada Department of Energy, Mines and Resources maps (1976). The following parameters were then recorded for each of the 1200 sampling points:

1. *Distance from the coast* — the minimum straight-line distance (km) from the sampling point to the nearest sea coast, including bays, but ignoring tidal rivers and estuaries.

2. *Distance from nearest road or building* — the minimum straight-line distance (m) from the sampling point to the nearest building or road (whichever was nearer), not counting as roads: "trails, cut-lines or portages".

3. *Elevation above sea level* — as estimated from map contour lines (25 foot intervals), the values being converted to metres.

4. *Size of wooded area* — the area (km^2) of the woodlot or forest as determined from the 1:50,000 maps, on which wooded areas are indicated by green shading.

An additional parameter was obtained from a map in MacDougall et al. (1988):

5. *Corn heat units* — an indicator of summer heat based on cumulative daily temperatures in the growing season. The corn heat units for each sampling point were read from contour lines in Figure 2 of MacDougall et al. (1988).

In addition, two parameters were obtained by computer from the Geographic Information System (G.I.S.) database for the province:

6. *Status in 1935* — the status of the sampling points in 1935 at the time of the first aerial photographic survey of the island. The forest boundaries in the aerial photographs had been transferred by Forestry Division photo-interpreters to maps which were subsequently digitised and incorporated into the G.I.S. system (Glen 1997). The database was queried

TABLE 4. Stand origin and management history attributes of the TWINSPAN forest-types as recorded in the field at the sampling points of the 1991 inventory. For each forest-type the percentage of its sampling points in each origin / management history class is given.†

STAND ORIGIN OR MANAGEMENT HISTORY ATTRIBUTE	FOREST-TYPES (and corresponding TWINSPAN groups)					All Points	χ^2 row sums
	Wet Rich Woodland (TSP Group 3)	Upland Hardwood Forest (TSP Groups 5 + 6 + 7)	Disturbed Conifer Forest (TSP Groups 8 + 9)	White Spruce Woods (TSP Group 10)	Black Spruce Forest (TSP Groups 13 + 14)		
Old field	17.9	**9.3 – *****	15.5	**58.5 + *****	10.0	18.4	**141.6**
Clear-cutting	7.1	6.8	6.7	2.2	2.5	5.9	5.8
Partial cutting/thinning	26.9	34.1	**42.8 + ****	**22.2 – ***	22.5	33.0	**17.7**
Burn‡	**3.2 – ****	**16.1 + *****	**6.4 – ***	7.4	10.0	10.2	**27.3**
Swamp	**16.7 + *****	**0 – *****	**0.70 – ***	**0 – ***	**11.3 + *****	3.4	**119.8**
Nothing evident	26.3	**32.5 + ***	26.1	**9.6 – *****	30.0	26.9	**20.5**
Other classes§	1.9	1.2	1.8	0	**13.8 + *****	2.2	**53.5**
χ^2 column sums	**89.7**	**56.6**	**20.1**	**149.9**	**70.1**		
NUMBER OF POINTS	156	428	283	135	80	1082	

†χ^2 test of association: total $\chi^2 = 386.5$ (d.f. = 24, $p < 0.001$), Cramer's V = 0.298). The percentages for which the corresponding χ^2 values were statistically significant are printed in bold (d.f. = 1, * - $p < 0.05$; ** - $p < 0.01$; *** - $p < 0.001$). For such percentages a '+' or '–' indicates the nature of the association between the particular forest-type and the origin class. Column or row χ^2 sums printed in bold are significant at $p < 0.01$ (for rows, df = 4; for columns, 6).

‡The significant positive association between the category 'burn' and upland hardwood (a forest-type that does not carry fire except under unusual circumstances), appears to be due to burning connected with past land clearance: the code "burn"' was used whenever charcoal was found in the soil pit, or when fire-scarred trees were present, the latter very infrequently.

§The significant positive association between Black Spruce forest and "other classes" is due entirely to the category 'bog': 10 of the 80 plots (12.5%) were classified as bog sites.

for the status of each of the 1200 sampling points in 1935, with their status being recorded as either forest-covered or cleared land.

7. *Soil series* — as defined by the Prince Edward Island Soil Survey (MacDougall et al. 1988). This was obtained from 1:10,000 soil series maps produced by the Soil Survey, as digitised and incorporated into the G.I.S. database. Where a map unit was listed as comprising more than one soil series, only the first named series was recorded.

Methods of data analysis

Two multivariate methods were used: Two-way Indicator Species Analysis (TWINSPAN or TSP), a classificatory technique, and Detrended Correspondence Analysis (DECORANA or DCA), an ordination technique. Both have been specifically developed for the analysis of plant community data (Hill 1979 a, b; Gauch 1982) and have been used extensively in forest and other vegetation studies, including several Canadian forestry studies (e.g., Jones et al. 1983; Sims et al. 1989; Bergeron et al. 1992; Bowling and Zelazny 1992). They are designed to be used in a complementary fashion on the same set of data, thus enabling both the recognition of plot groups comprising distinct plant community types, and the spatial ordering of these groups and their component plots in terms of their overall similarity to each other.

TWINSPAN and DECORANA were applied to the ground flora data using Cornell University computer programs (Hill 1979 a, b) modified to enable the analysis of all 1200 plots in a single run. Seventy-one of the 1200 plots were omitted beforehand from the analysis, 18 in which no ground flora species had been recorded and 53 for which no trees were recorded in the area of the sampling point. Of the 225 taxa recorded in the Inventory, 13 of the 16 non-specific genera were omitted from the analyses (the generic categories retained were *Amelanchier, Sphagnum,* and *Mnium*). All plant species occurring in fewer than five plots were also omitted, which resulted in two further plots being reduced to zero species, and these were also omitted from the analysis. In the end, 1127 plots and 128 taxa were subjected to TWINSPAN and DECORANA.

The DECORANA ordination and TWINSPAN classification are based entirely on the ground flora data. The second stage of the analysis consisted of the interpretation of the products of these analyses (i.e. the plot groups and two-dimensional graphs). The groups were first described in terms of their ground flora composition and then each was interpreted using the independent environmental data (including data on the tree canopy). Differences between the various TWINSPAN groups were compared statistically, while the scores for the plots on the DECORANA axes were tested for correlation and/or association with the independent environmental data. In this second stage of the analysis dBASE IV was used to sort

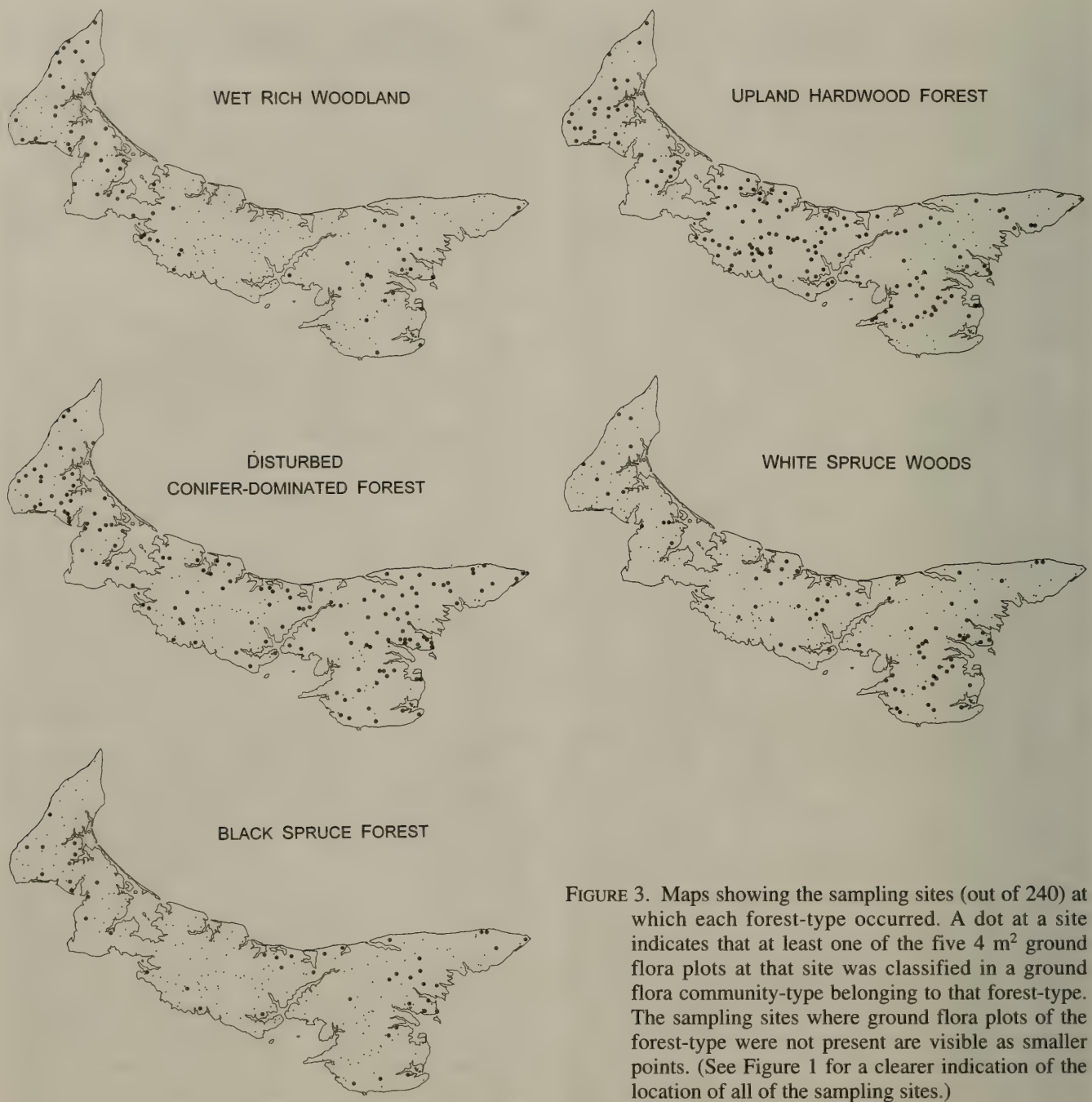

FIGURE 3. Maps showing the sampling sites (out of 240) at which each forest-type occurred. A dot at a site indicates that at least one of the five 4 m^2 ground flora plots at that site was classified in a ground flora community-type belonging to that forest-type. The sampling sites where ground flora plots of the forest-type were not present are visible as smaller points. (See Figure 1 for a clearer indication of the location of all of the sampling sites.)

the plant and environmental data for the various TWINSPAN groups, and the computer package SPSS (Statistical Package for Social Scientists) (Norusis 1990) was used in the statistical analyses. Among the tests applied were one-way analysis of variance (with the Scheffé multiple comparison test), the χ^2 test of association (including Cramer's V), and Pearson's correlation coefficient.

After the multivariate analyses had been completed, in order to verify in the field the validity of the TWINSPAN groups, and to record photographically the appearance of their ground flora, in the summer of 1994 (using the same cruise line compass bearings and distances as in the 1991 field survey) the sampling points of 26 plots selected as representative of the eleven TWINSPAN groups were visited.

Results

TWINSPAN classification of the ground flora plots

The TWINSPAN classification of the sample plots to the fourth division level generated fifteen ground flora plot groups (Figure 2). Disregarding the four groups with fewer than ten plots leaves eleven groups, ranging in size from 12 to 196 plots (see Appendix 1 for the ground flora species frequencies for each group). Subsequent analysis, as outlined below, indicates that nine of these eleven groups belong to five forest-types.

Examination of the tree canopy composition (Table 1) indicates that the first division largely acts to separate the plots having a large broadleaved component in their canopies (the 595 plots to the left in Figure 2) from those with a high conifer component (the 532

TABLE 5. The status in 1935 (as either forest-covered or cleared land) of the sampling points of the TWINSPAN forest-types, based on photo-interpretative analysis of a 1935 aerial photographic survey of the island. For each forest-type the percentage of its sampling points in each category is given.†

	FOREST-TYPES (and corresponding TWINSPAN groups)						
STATUS in 1935	Wet Rich Woodland (TSP Group 3)	Upland Hardwood Forest (TSP Groups 5 + 6 + 7)	Disturbed Conifer Forest (TSP Groups 8 + 9)	White Spruce Woods (TSP Group 10)	Black Spruce Forest (TSP Groups 13 + 14)	All Points	χ^2 row sums
Forest-covered	79.5	**86.4 + ****	74.2	**24.4 – *****	67.5	73.1	**55.3**
Cleared land	20.5	**13.6 – *****	25.8	**75.5 + *****	32.5	26.9	**150.6**
χ^2 column sums	3.2	**38.7**	0.17	**162.6**	1.2		
NUMBER OF POINTS	156	428	283	135	80	1082	

†χ^2 test of association: total $\chi^2 = 206.0$ (d.f. = 4, $p < 0.001$), (Cramer's V = 0.308). The percentages for which the corresponding χ^2 values were statistically significant are printed in bold (d.f. = 1, * - $p < 0.05$; ** - $p < 0.01$; *** - $p < 0.001$). For such percentages a '+' or '–' indicates the nature of the association between the particular forest-type and the 1935 status class. Column or row χ^2 sums printed in bold are significant at $p < 0.01$ (for rows, d.f. = 4; for columns, 1).

plots to the right). The broadleaved plots were then split into two groups, the smaller group (Group 3 — 156 plots) being those of a more base-rich and wetter swamp-type woodland (Tables 2 and 3) in which Red Maple (*Acer rubrum*) predominates, with American Elm (*Ulmus americana*), White Ash (*Fraxinus americana*) and White Cedar (*Thuja occidentalis*) occurring at low frequencies (Tables 1). The larger group (430 plots) consists of the dryer or 'upland' hardwoods, further divided into three sub-groups (Groups 5, 6 and 7) which appeared to differ primarily in relation to the amount of past human disturbance: Group 5 showed the least disturbance: of the three groups, it had the highest proportion of the tolerant hardwood species (31% of its woody biomass comprised Sugar Maple (*Acer saccharum*), American Beech (*Fagus grandifolia*) and Yellow Birch (*Betula alleghaniensis*)), as well as the oldest and tallest trees of any group (see Sobey (1995) for further details).

The 532 conifer-dominated plots in Figure 2 were divided into a larger group (439 plots) showing associations with dryer and less acid conifer woods (Tables 2 and 3), and a smaller group (93 plots), associated with wetter and more acid Black Spruce (*Picea mariana*)-dominated woodland. The larger group ended up as four groups, two of which (Groups 8 and 9) were quite similar and appear to represent disturbed conifer-dominated forest on dryer soils (these plots are dominated by Balsam Fir (*Abies balsamea*) with smaller contributions from Red and White spruce (*Picea rubens*, *P. glauca*) (see Table 1); the third group (Group 10) consisted largely of the plots of old field White Spruce woods (Tables 1, 4, 5); and the fourth group (Group 11 with only 21 plots) was a species-poor group, which analysis and field observation (Sobey 1995) indicated to be more closely related to the broad-leaved plots than to the conifer plots. The 93 plots of the Black Spruce-dominated forest ended up as three groups, one (Group 12, with only twelve plots) containing an odd mixture of acid and more nutrient-demanding ground flora species. Analysis and field observation suggests it represents a plot-type transitional between Groups 3 and 13 (see Appendix 1). The other two groups comprise the Black Spruce forest proper, sub-divided into a wetter bog-type forest (Group 13) and a drier lichen-heath-type forest (Group 14) (see Appendix 1).

In summary, the eleven ground flora community-types can be taken to represent five forest-types, each showing its own distribution pattern on the island (Figure 3) (see also Appendix 2 for a summary of the factors associated with each forest-type): a wet species-rich swamp-type woodland (Group 3); upland hardwood forest (Groups 5, 6 and 7); disturbed conifer-dominated forest (Groups 8 and 9); old field White Spruce woods (Group 10); and Black Spruce-dominated forest (Groups 13 and 14). These forest-types show striking differences in geographical distribution (Figure 3), topography (Table 6), soil

TABLE 6. The mean (± SE) of the typographic attributes of the TWINSPAN forest-types. The letters following the value refer to the Scheffé multiple comparison test (see footnote).

	FOREST-TYPES (and corresponding TWINSPAN groups)						
TOPOGRAPHIC ATTRIBUTE	Wet Rich Woodland (TSP Group 3)	Upland Hardwood Forest (TSP Groups 5 + 6 + 7)	Disturbed Conifer Forest (TSP Groups 8 + 9)	White Spruce Woods (TSP Group 10)	Black Spruce Forest (TSP Groups 13 + 14)	ONE-WAY ANOVA† F	p
Elevation (m)	19.5 (1.2) a*	43.7 (1.1) a b*	25.3 (0.98) b c*	36.1 (1.8) a b c d*	19.4 (1.5) b d	71.0	0.000
Slope (%)	0.84 (0.15) a*	3.3 (0.24) a b	2.4 (0.23) a b	3.5 (0.36) a b	0.76 (0.19) b*	16.2	0.000
Distance to coast (km)	4.7 (0.32) a*	6.8 (0.20) a b*	5.3 (0.24) b c*	6.7 (0.42) a c d*	4.8 (0.44) b d	12.1	0.000
Distance to road (m)	454 (26)	505 (15) a*	493 (22) b*	379 (23) a b	391 (47)	5.1	0.000
Corn heat units	2304 (3.8) a*	2323 (2.4) a b*	2303 (3.0) b	2308 (3.8) c*	2286 (4.7) b c	14.6	0.000
NUMBER OF POINTS	156	428	283	135	80		

†ONE-WAY ANOVA: Scheffé test: means followed by a letter are significantly different ($p < 0.05$) from a mean with the same letter with an asterisk: e.g. : 'a' is significantly different from 'a*'.

FIGURE 4. DECORANA ordination of the ground flora plots along the first and second axes. The boundary lines enclose the main cluster of plots for each of the eleven TWINSPAN groups.

chemical and drainage properties (Tables 2 and 3), and in management history (Tables 4 and 5). Three of these forest-types (the wet rich woodland, the upland hardwood forest and the Black Spruce forest) are recognisable descendants (though heavily modified) of forest-types likely to have occurred at the time of European settlement (compare Erskine 1960), while the other two (the disturbed conifer-dominated forest and the White Spruce woods) appear to be more the product of successional processes associated with the effects of human disturbance and forest clearance.

DECORANA ordination of the ground flora plots

Of the four axes generated by the DCA ordination it was found that the first two (with eigenvalues of 0.65 and 0.51 respectively) gave an ecologically meaningful picture of the relationship between the plots. The position of the eleven plot groups along these axes is shown in Figure 4, while in Figure 5 the eleven groups have been combined into the five forest-types discussed above. Figure 4 supports and clarifies the interrelationships between the plot groups evident from the classification: Group 3, the wet rich woodland, is largely spatially separate from the other groups; the three upland hardwood groups (5, 6 and 7) overlap in position, 6 and 7 more so than the less disturbed Group 5; the two groups of disturbed conifer-dominated forest also overlap but Group 8 lies more towards the hardwood Groups 6 and 7, while Group 9 overlaps with the Black Spruce Group 14; Group 12, whose species make-up overlapped both Groups 3 and 13 (see Appendix 1) does indeed lie between Groups 3 and 13; Groups 13 and 14 (the Black Spruce groups) lie near each other; while Group 10 (the White Spruce group) overlaps all of the other conifer groups (8, 9, 13, and 14). Figure 5 indicates that when the groups

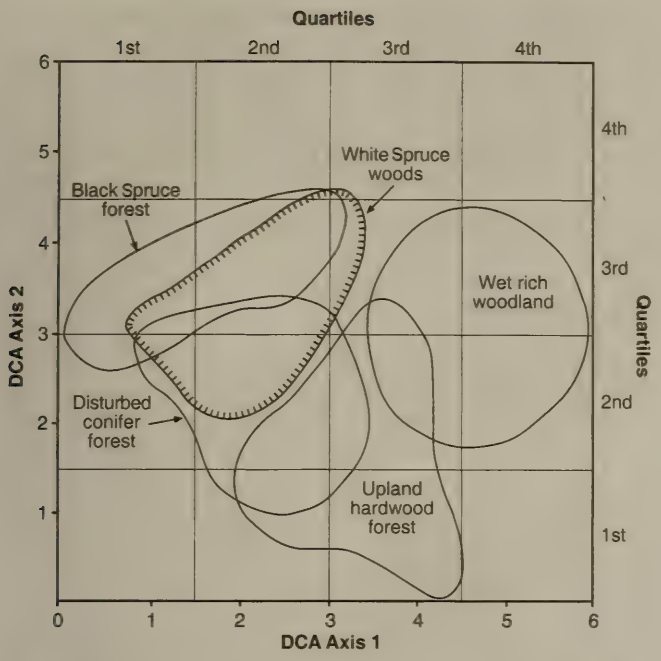

FIGURE 5. DECORANA ordination (along the first and second axes) showing the main cluster of plots for the five principal forest-types. (The two axes have been sub-divided into quartiles to facilitate χ^2 tests of association for the qualitatively measured attributes of the plots — see Tables 8 and 9.)

similar in species composition are combined into five forest-types, four of the groups occupy reasonably separate areas of the ordination while the fifth (Group 10, the White Spruce woods) shows more overlap.

DECORANA ordination: environmental factors

To determine whether any of the recorded environmental factors showed a relationship with the plot ordination, two types of statistical test were carried out: for the variables measured quantitatively Pearson's correlation coefficients were calculated between each factor and the plot scores along the axes (Table 7), while for the categorical variables, χ^2 tests were used to examine the association between the attribute classes and axis position when the axes were divided into quartiles (Tables 8 and 9).

The analyses indicate that two groups of factors show a strong association with the overall ordination of the plots. One group is connected with soil moisture levels: attributes indicative of high soil moisture (i.e., poor and imperfect drainage (as determined from the soil pits), poorly and imperfectly-drained soil series (as determined from soil survey maps), a high water table, level ground) all had significant positive associations with the upper ends of each of the two axes (Tables 8 and 9); i.e., the region occupied on the first axis by the wet rich woodland, and on the second axis by the Black Spruce forest, as well as part of the wet rich woodland and White Spruce woods (Figure 5). Consistent with this finding was the fact that on the second axis (though not the first), elevation above sea level was negatively correlated (Table 7) at a fairly high level (-0.40), and there were similar negative correlations (though smaller) for other elevation-associated topographic factors (i.e. slope, distance to the coast, and cumulative heat units).

The other group of attributes showing a significant relationship with the ordination were "stand origin / management history" and "status in 1935" (both indicative of the past history of a site, particularly human disturbance). These factors showed a high level of association with the second axis (Table 9): stands recorded as "old field" and as "cleared land in 1935" occurred much more frequently than expected due to chance in the combined third and fourth quartiles — the part of the axis where most of the plots of the White Spruce woods lie. By contrast, the first quartile, in which the apparently least human-disturbed of all of the ground flora groups occurred (Group 5, of the upland hardwood forest), was positively associated with only "nothing evident" (i.e., no evidence of human disturbance/management) and "burn" — for the latter category, see the footnote of Table 4.

The analysis of both the quantitative and qualitative attributes thus indicates that elevation, soil drainage and management history show significant associations with the overall distribution of the plots in the first two dimensions of the ordination space. This suggests that they are likely to play a significant role in determining the ground flora species make-up of the forest-types. The results of the ordination are also consistent with the pattern emerging from the comparison of the properties of the individual TWINSPAN forest-types, as evident in the various comparative tables (Tables 1 to 6).

TABLE 7. Pearson's correlation coefficients between the quantitatively measured topographic attributes and soil properties (of the humus layer) and the scores of the sampling points on the first two axes of the DECORANA ordination. (Degrees of freedom vary between 1114 and 1198.)†

	AXIS 1	AXIS 2
TOPOGRAPHIC ATTRIBUTES		
Elevation	ns	-0.40***
Slope	-0.07**	-0.16***
Distance to coast	ns	-0.16***
Distance to road	0.068*	-0.12***
Corn heat units	0.090**	-0.17***
SOIL PROPERTIES		
pH	ns	0.14***
% Carbon	-0.09 ***	ns
Nitrogen	ns	ns
Phosphorus	-0.16***	-0.20***
Potassium	-0.24***	-0.21***
Calcium	-0.10***	0.21***
Magnesium	-0.08 **	ns

†Probabilities: *** - $p < 0.001$; ** - $p < 0.01$; * - $p < 0.05$; ns - not significant.

TABLE 8. χ^2 analysis of the association between selected qualitatively-categorized soil and forest stand properties of the sampling points, and the position of the points along the first DECORANA axis, as subdivided into four equal quartiles (see Figure 4). For each attribute those individual classes whose χ^2 contributed significantly (d.f. = 1) to the total χ^2 value, are listed under the quartiles with which they had a *positive* association.

ATTRIBUTE	χ^2 (d.f.)	Cramer's V	Quartile 1	Quartile 2	Quartile 3	Quartile 4
SOIL PROPERTIES:						
Soil drainage (from soil pits)	175.8*** (9)	0.228		Well-drained*		Moderately well drained** Imperfectly-drained* Poorly-drained ***
Soil drainage (from soil series maps)	178.7*** (9)	0.229	Rapidly-drained***		Well + moderately drained *	Imperfectly-drained** Poorly-drained***
Root restriction factors	119.9*** (3)	0.326				High water table***
Slope	46.9*** (3)	0.204				Level land***
STAND PROPERTIES:						
Forest type	197.4*** (12)	0.241	SS *** SH *		HH***	
Stand origin / management history	67.9*** (18)	0.141				Swampy***
Status in 1935	37.4*** (3)	0.182	Cleared ***			

Probabilities: *** = $p < 0.001$; ** = $p < 0.01$; * = $p < 0.05$.

It is notable that although there were significant differences in the soil chemical factors between some of the forest-types (Table 3) (the wet rich woodland especially differed from all of the others), none of the soil factors show much correlation with either of the axes (Table 7). This is perhaps not surprising given the limited variation in soil parent materials on the island.

Discussion

For the first time in the botanical history of Prince Edward Island we have a quantitative record of the woodland plant community-types occurring on the island. What is more, this is based on a large objectively-selected sample that has been analysed using objective techniques of classification and ordination. We are thus now able to define the forest-types on Prince Edward Island as they exist at the end of the twentieth century: TWINSPAN has led to the recognition of eleven ground flora groups representing five main forest-types: a wet species-rich and base-rich swamp-type woodland; upland hardwood forest; disturbed conifer-dominated forest; old field White Spruce woods; and Black Spruce forest. Because of the large amount of data of various kinds collected in this study we are able to describe each of these forest-types in considerable detail, not only in terms of their ground flora, but also their tree components, and the topographic, historical/management and soil factors acting on them.

The DECORANA ordination has indicated that in overall terms two environmental factors, soil drainage and forest disturbance, appear to be particularly significant in determining the forest-types of the island. It is they (and especially drainage indicators) that show a high degree of association with the position of the plots along the first two ordination axes. The importance of these two factors was also borne out in the comparative analysis of the TWINSPAN forest-types: differing soil moisture levels are an important factor distinguishing some of the forest-types (Table 2). At the same time the importance of human-associated forest disturbance and clearance is evident throughout the analysis: all of the TWINSPAN forest-types have a proportion of plots showing evidence of various types of human intervention (e.g. clear-cutting, partial cutting, old field status) (Tables 4 and 5), and it is human activity *per se* which is the most important factor accounting for one of the forest-types (White Spruce woods), and which contributes to a second type, the disturbed conifer-dominated forest. The degree of human-disturbance also appears to differentiate the three upland hardwood plot groups.

It is not possible to compare these findings in any depth with previous descriptions of the forests of the island, as there are no previous studies of comparable detail. However, it is evident that the general points emerging from this study do not conflict with the brief

TABLE 9. χ^2 analysis of the association between selected qualitatively-categorized soil and forest stand properties of the sampling points, and the position of the points along the second DECORANA axis, as subdivided into four equal quartiles (see Figure 4). For each attribute those individual classes whose χ^2 contributed significantly (d.f. = 1) to the total χ^2 value, are listed under the quartiles with which they had a *positive* association.

ATTRIBUTE	χ^2 (d.f.)	Cramer's V	Quartile 1	Quartile 2	Quartiles 3 + 4
SOIL PROPERTIES:					
Soil drainage (from soil pits)	245.3*** (6)	0.269	Well-drained***		Imperfectly-drained*** Poorly-drained***
Soil drainage (from soil series maps)	181.8*** (6)	0.284	Well/moderately drained***		Imperfectly-drained** Poorly-drained***
Root restriction factors	82.1*** (2)	0.269			High water table***
Slope	93.1*** (2)	0.287	Sloping ground**		Level ground***
STAND PROPERTIES:					
Forest type	308.5*** (8)	0.369	HH***	SH* HS*	SS***
Stand origin / management history	214.8*** (12)	0.308	Burn*** Nothing evident***	Partial cut*	Old field*** Swampy*** Boggy***
Status in 1935	60.3*** (2)	0.231	Forested ***		Cleared ***

Probabilities: *** = $p < 0.001$; ** = $p < 0.01$; * = $p < 0.05$.

and qualitative forest descriptions contained in those regional and national studies that have included the island (i.e., Halliday 1937; Rowe 1959; Loucks 1961). Nor are they in disagreement with the three island-based studies that contain limited qualitative descriptions of the internal variation in the island's forests (Stilgenbauer 1929; Erskine 1960; MacDougall et al. 1988). Generally, all of these previous studies considered soil drainage to be especially important in determining the type of forest occurring in particular areas, even if they only did so by making the general and not wholly accurate comment that the upland areas were occupied by tolerant hardwoods and the lowlands by coniferous forest. However, it was only Erskine (1960) (in the most detailed of these previous descriptions) who recognised a wet rich lowland forest corresponding to the wet rich woodland of this study. By contrast MacDougall et al. (1988) speculated that the limited differences in the fertility of island soil types appeared to have little effect on tree species composition. All of these previous studies also recognised the very important effects of human disturbance on forest differentiation, though those whose aim was to describe the forest in its hypothetical undisturbed state give it less coverage (Halliday 1937; Rowe 1959; Loucks 1961).

This study now provides quantitative data to back up these previous speculations: on an island in which there is a limited range of soil parent materials (most are derived from sandstone and similar rocks (MacDougall et al. 1988)) and of climatic variation, the principal intrinsic factor responsible for the variation in the forest vegetation is variation in soil drainage. Drainage in turn is determined by the interaction between topographic factors (key factors in this respect are elevation and slope), and the nature, especially the texture, of the soil parent material. In addition, in the areas of poor drainage, there is then an important differentiation (due presumably either to slight differences in the base-richness of the soil parent materials or to differences in the chemical richness of lateral drainage water), between the lower pH base-poorer soils with higher C/N ratios supporting Black Spruce forest, and the higher pH more base-rich soils with lower C/N ratios supporting a swamp-type forest in which deciduous trees, especially Red Maple, predominate.

Superimposed on any differences caused by drainage are the effects of almost three centuries of human interference, involving the initial forest clearance for the creation of farmland (which reached its maximum in the early twentieth century), and the continual exploitation of the remaining forest stands for timber and firewood. In this century especially there has also been the abandonment of much of the poorer farmland (Stilgenbauer 1929; Clark 1959; Glen 1997), resulting in its recolonisation by trees in a process of secondary succession.

That the information that has emerged from this study is in agreement with the general observations of the few previous workers who have had an interest in the island's forests is especially pleasing in view of the small plot size (4 m^2) used for the assessment of the ground flora, a size imposed by financial constraints. (Usually much larger plot sizes [e.g., 200 m^2 (Bunce 1982) or 450 m^2 (Zelazny et al. 1989)] are used in forest studies.) Even though the 4 m^2 plot has been shown to have picked up on average only a third

of the ground flora species in the *c.*1000 m² area around a sampling point (Sobey 1993), this has not prevented statistically-distinctive ground flora groups and forest-types emerging in the multivariate analysis. Furthermore, these forest-types, as well as some of the groups, have proved to be recognisable in the field as distinct vegetation-types. They are also consistent with previous information on the forest vegetation of the island, and at the same time have been amenable to logical explanation in terms of environmental and historical factors. Undoubtedly a larger plot size, if combined (as is usual in such studies) with the omission in the field of those sites that were obviously heterogeneous, might have led to the production of ground flora groups that were more distinctive and discrete, with for example the plots showing less overlap in the DECORANA ordination (Figure 4), but this would also have masked an important feature of the island's forests (or any forest for that matter): forest vegetation is likely to be continuously variable in the composition of both its tree canopy and ground flora. In fact, a larger plot size, without the simultaneous elimination of sample plots containing obviously intermediate vegetation-types, would have led to less distinction between the groups. And since any process of eliminating plots would have inevitably involved questionable subjective decisions, a small plot size has thus had benefits, an additional one being that a much larger number of plots were able to be recorded within the limits imposed by the financial constraints.

It must however be stated that it is likely that any forest-type with a limited distribution may not have been picked up at the 1200 sampling points, or at least not in sufficient numbers to constitute a recognisable group in the analysis. With reference to Erskine's (1960) floristic study of the island, as well as to special habitat surveys (Taschereau 1974; Anonymous 1982) and to New Brunswick studies (e.g., Zelazny et al. 1989), some forest-types that are likely to constitute distinct plant communities on the island (and undoubtedly these would have been more common in the past), but which have not emerged in the analysis are: Cedar woods (only 40 sampling points in all contained White Cedar, most of these were classified in the wet rich woodland group); a fern- and herb-rich variant of the upland hardwood forest (containing for example White Ash (*Fraxinus americana*) or Ironwood (*Ostrya virginiana*) in the canopy); stream valley woodlands (some with American Elm and Black Ash (*Fraxinus nigra*)); Pine woods (both White and Red: *Pinus strobus, P. resinosa*); and Hemlock (*Tsuga canadensis*) stands (the latter two now very rare). To obtain a sufficiently sized sample of such rare woodland types, we would need to actively search for and then sample such sites in a separate selective inventory.

The maps showing the distribution of the sampling sites (Figure 3) give an indication of the spatial distribution of the five forest-types on the island. The distinctive spatial patterns evident greatly add to the limited qualitative information available before the 1991 Inventory (e.g., Erskine 1960). However, by making use of another element in the 1990-92 forest inventory (the 1990 aerial photographic survey of the island), the next stage in the study will be to map the total distribution on the island of all of the stands of the five forest-types.

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APPENDIX 1. The percentage frequency of the ground flora species in the TWINSPAN ground flora plot groups. (TWINSPAN groups of fewer than 10 species have been omitted.) Only species ≥ 10% frequency in at least one group are listed. Frequencies printed in bold were significantly greater (χ^2 test, d.f. = 1, $p < 0.001$) than the frequency for the same species in all 1200 plots — such species are termed "selective" (*sensu* Bunce 1982) for the plot group.[1] The species are listed in the same order as in the data matrix table generated by the TWINSPAN analysis.

	TWINSPAN GROUND FLORA PLOT GROUPS											
	3	5	6	7	8	9	10	11	12	13	14	
SPECIES	Wet Rich Wood-land		Upland Hardwood Forest		Disturbed Conifer-domindated Forest		White Spruce Woods	*	*	Black Spruce Forest		All 1200 plots
Alnus incana	**12**								**25**			2.9
Aster umbellatus	**16**				7	7			17	10		5.4
Ilex verticillata	**6**								**25**	7		12.1
Ptilidium pulcherrimum	**13**	6			5	5						4.6
Aster puniceus	**18**		6				9		8			5.5
Dryopteris cristata	**8**								**33**			2.0
Viola spp.	8						7		**33**			4.2
Epilobium angustifolium	**15**		6			6						5.2
Equisetum spp.	**12**											2.8
Equisetum sylvaticum	**15**								8			3.0
Fragaria virginiana	**33**					5	6		25			7.7
Galium triflorum	**33**		9				7		8			7.3
Ranunculus repens	**20**						5					3.8
Rhytidiadelphus triquetrus	**26**								25			5.2
Rubus pubescens	**69**		5		8				50			12.4
Lycopus uniflorus	**10**											1.7
Osmunda cinnamomea	**35**				7				**75**	17		7.9
Typha latifolia	**6**								17			1.1
Athyrium filix-femina	**28**	6							8			5.4
Cornus sericea	**30**								17			4.8
Galium palustre	**13**											1.8
Impatiens capensis	**44**								25			6.3
Mitella nuda	**31**								8			4.8
Mnium spp.	**31**								8			5.0
Onoclea sensibilis	**36**								8			5.3
Ribes lacustre	**14**								8			2.3
Thalictrum pubescens	**10**											1.5
Gymnocarpium dryopteris	**17**											3.3
Phegopteris connectilis	**10**											2.0
Acer spicatum	6	**18**										2.6
Taxus canadensis	**25**	**64**	9	6	7				17			11.2
Dryopteris carthusiana	**42**	**92**	**39**	31	19	5						26.3
Oxalis acetosella	5	**13**	6									2.9
Viola cucullata	10		8	6			5		8			4.8
Viola macloskeyi	**33**	6	**31**	19	12	9	7					16.3
Dennstaedtia punctilobula			15	**67**	12							14.6
Lycopodium annotinum				**23**								4.4
Huperzia lucidula		5		**10**								2.8
Lycopodium obscurum		14	13	**63**	10	18		19				15.3
Medeola virginiana				**14**								2.7
Trillium undulatum		14	**33**	**44**	10	8	5					15.3
Viola blanda			10	9			5					3.8
Aralia nudicaulis	29	44	**56**	45	**52**	19	7	10	8			32.5
Monotropa uniflora				7				10				2.2
Rubus canadensis	12	9	**16**		8		7					8.5
Aster acuminatus	13	6	**24**		17	8						10.0
Pyrola elliptica	10		6	5	7		5		8			5.0
Trientalis borealis	31	27	**66**	**63**	60	51	36	33	33	7	10	44.3
Clintonia borealis	15	26	**35**	9	**47**	13				28		19.8
Coptis trifolia	19		8		**22**	14			**50**	14	6	10.6
Grass spp.	**18**		6				16					7.6

(Continued)

APPENDIX 1. ***Continued***

	TWINSPAN GROUND FLORA PLOT GROUPS											
	3	5	6	7	8	9	10	11	12	13	14	
SPECIES	Wet Rich Wood-land	Upland Hardwood Forest			Disturbed Conifer-domindated Forest		White Spruce Woods	*	*	Black Spruce Forest		All 1200 plots
Dicranum scoparium	8	14	21	16	**41**	24	13	**100**	8	7	6	19.8
Moss spp.	5	6	7	6			6	10				4.8
Maianthemum canadense	32	38	74	77	**85**	**92**	56	48	33	10	18	58.8
Sorbus americana	9		15		15	5	12			7		8.3
Hieracium aurantiacum							**19**					5.1
Polytrichum commune			7	20	23	**37**	**46**	29		10	25	19.0
Aster spp.	5						**14**					4.2
Veronica officinalis							**13**					3.2
Amelanchier spp.			10		15	**18**	7		17		16	8.3
Cornus canadensis	27	25	29	9	**61**	**86**	10		83	59	57	35.2
Cypripedium acaule										**31**	10	2.8
Hylocomium splendens	12				**16**		7		**58**	17	6	6.7
Linnaea borealis	11				**33**	**22**			8			10.2
Pteridium aquilinum			8	11	19	**73**			8		**49**	16.8
Viburnum nudum	20		5	7	**62**	**58**	21		67	45	49	26.8
Dicranum polysetum					**20**	15	19		8	14	**45**	10.1
Epigaea repens						**11**					**18**	2.2
Melampyrum lineare						5	6		8		10	2.5
Carex spp.	**44**	8	23	15	19	16	25	14	58	48		22.3
Pleurozium schreberi	25	8	13	9	**72**	**69**	**82**	71	75	72	**80**	41.8
Ptilium crista-castrensis						7	**16**		17		**18**	4.3
Vaccinium angustifolium					15	**48**	26		25	21	**69**	14.8
Vaccinium myrtilloides					12	**31**	7		17	**31**	**31**	8.2
Cladina rangiferina											**25**	1.8
Gaultheria procumbens						6				7	**31**	2.7
Gaylussacia baccata										**21**	**10**	1.3
Kalmia angustifolia					7	**46**			**58**	**66**	**90**	13.8
Ledum groenlandicum									17	**31**	**37**	2.8
Nemopanthus mucronata					**21**	7			**42**	**72**	22	8.1
Chamaedaphne calyculata										**14**		0.6
Rhododendron canadense										10	**35**	2.3
Gaultheria hispidula	5								8	**41**	8	3.1
Smilacina trifolia									**58**	**17**		1.7
Sphagnum spp.	**29**				17				**92**	**97**	**35**	13.0
Cladina stellaris											**12**	0.7
Number of plots	156	77	196	155	165	118	135	21	12	29	51	
Mean no. of species/plot†	13.7	5.6	7.7	6.9	9.8	9.5	6.5	4.0	13.9	8.9	8.9	8.6
Standard error	0.44	0.34	0.23	0.20	0.29	0.27	0.29	0.44	2.2	0.60	0.38	0.13
Scheffé test†	a*	a b c d e g	a b c d g*	a b c d	a b*	a c*	a b c d d e f g	a b c	d*	a f*	a e*	

1. The following additional ground flora species were 'selective' for the the various TWINSPAN groups but occurred at less than 10% frequency: **Rich Wet Woodland**: *Ribes hirtellum, Caltha palustris, Eupatorium maculatum, Prunus virginiana, Equisetum arvense, Circaea alpina, Ribes glandulosum, Lonicera canadensis, Corylus cornuta, Rosa virginiana.* **Upland Hardwood Forest**: TSP Group 6: *Smilacina racemosa, Cornus alternifolia*; TSP Group 7: *Smilacina racemosa, Monotropa uniflora.* **Disturbed Conifer-dominated Forest**: TSP Group 8: *Bazzania trilobata.* **White Spruce Woods**: *Myrica pensylvanica.*

*TWINSPAN Group 11 was a species-poor hardwood-related plot-type and Group 12 was a wet species-rich plot-type transitional between TWINSPAN Groups 3 and 13.

†Mean number of species per plot: One-way ANOVA (d.f. = 10): $F = 53.0$, $p < 0.001$. Scheffé test: a mean with the same letter is significantly different ($p < 0.05$) from a mean with the letter followed by an asterisk (e.g. "a" is significantly different from "a*").

APPENDIX 2. Summary descriptions of the TWINSPAN-derived forest-types (based largely on the data contained in Tables 1 to 6).

WET RICH WOODLAND (TWINSPAN Group 3: 156 plots — 13.8%)
A forest-type of frequent occurrence, especially at low elevation sites of varying sizes in the western region, as well as parts of the eastern region of the island (see Figure 1 for region boundaries); it is associated with comparatively less acid but poorly-drained soils. The tree canopy contains a mixture of broad-leaves and conifers, with Red Maple (*Acer rubrum*) predominating, and with low but notable levels of White Cedar (*Thuja occidentalis*), White Ash (*Fraxinus americana*), American Elm (*Ulmus americana*) and Speckled Alder (*Alnus incana*). It is a species-rich community-type at all levels (in trees, shrubs and ground flora), characterised by 44 selective ground flora species*, an exceptionally large number. Key site factors associated with the group are low elevation, level land, poor soil drainage, poorly and imperfectly drained soil series, higher pH and base content, lower C/N ratio. Key stand factors: mixed Red Maple-dominated forest, older trees, medium stocking rate. This forest-type appears to be a derivative of the pre-European settlement lowland Red Maple forest (*sensu* Erskine 1960) — though with considerable effects due to cutting and other disturbances.

UPLAND HARDWOOD FOREST (TWINSPAN Groups 5 + 6 + 7: 428 plots — 38.0 %)
A forest-type of widespead occurrence, well-scattered throughout the central region and in specific areas in the eastern and western regions. The tree canopy is dominated by hardwoods, especially Red Maple (*Acer rubrum*), with a notable contribution by the tolerant hardwood species (Sugar Maple (*Acer saccharum*), Yellow Birch (*Betula alleghaniensis*) and American Beech (*Fagus grandifolia*)). There is also a minority softwood component especially of Balsam Fir (*Abies balsamea*), and the presence of Trembling Aspen (*Populus tremuloides*) and White Birch (*Betula papyrifera*) is indicative of past and continuing human disturbance. The ground flora is of poor to moderate species-richness, and its three sub-groups are characterised collectively by nineteen different selective ground flora species. Key site factors: moderate to higher elevations, sloping ground, well-drained soils, well-drained soil series, lowish to moderate organic matter, varying levels of past forest clearance and cutting, small to moderatè woodland size. Key stand factors: hardwood-domination. This forest-type is equivalent to the pre-European settlement tolerant hardwood forest of the uplands (*sensu* Erskine 1960), though subject to varying levels of past and current human disturbance.

DISTURBED CONIFER-DOMINATED FOREST (TWINSPAN Groups 8 + 9: 283 plots — 25.1%)
A forest-type of frequent occurrence, especially common in larger woodland areas at moderately low elevations in the east and in the far west. It comprises conifer-dominated forest on soils of varying drainage properties — though not on the wettest. The tree canopy is dominated by softwoods, especially Balsam Fir (*Abies balsamea*), with White, Black and Red spruce (*Picea glauca*, *P. mariana*, *P. rubens*). The ground flora is of moderate species-richness, with 20 different selective species for the two sub-groups. Key site factors: highish levels of partial-cutting/thinning, highish level of past forest clearance, generally good drainage. Key stand factors: softwood-domination, moderate stocking rate. It is difficult to equate this forest-type with any of the climax forest-types of Erskine (1960) (though it may include areas that in the pre-European period were occupied by pine forests). Rather it appears to largely represent a forest-type heavily affected by past and continuing human exploitation.

WHITE SPRUCE WOODS (TWINSPAN Group 10: 135 plots — 12.0%)
A forest-type of common occurrence comprising woodlands of varying sizes on well-drained soils at moderate elevations. It has a distinct distributional bias toward the eastern end of the island. This forest-type has a marked association with land formerly cleared for agriculture. The tree canopy is dominated by a single species, White Spruce (*Picea glauca*), which is generally youngish, even-aged, and of high density. It is a species-poor community at all levels (i.e. in ground flora, shrubs and trees), characterised by only seven selective ground flora species, most of which are either mosses or weedy aliens. Key site factors: "old field" sites; i.e., formerly cleared land, well and rapidly drained soils, sloping land, lowish organic matter content. Key stand factors: White Spruce-domination, immature trees, low tree age and height, high stocking rate. This forest-type corresponds to the successional "old field" White Spruce woods of Erskine (1960).

BLACK SPRUCE FOREST (TWINSPAN Groups 13 + 14: 80 plots — 7.1%)
A rather uncommon forest-type occurring on areas of varying drainage properties at lower elevations especially in parts of the western and eastern regions. The tree canopy is dominated by conifers, above all Black Spruce (*Picea mariana*), with some Red Spruce (*Picea rubens*) and Tamarack (*Larix laricina*). The ground flora is of moderate species-richness, with 20 different selective species in its two sub-groups. Key site factors: level ground, soils of varying drainage from poor to good, swamp and bog characteristics, low pH, high C/N ratio. Key stand factors: Black Spruce-domination, low stocking rate, low tree height, medium tree age. This forest-type corresponds to the lowland Black Spruce forest of Erskine (1960). The two sub-groups (Groups 13 and 14) appear to represent ecologically-valid variants of this forest-type, the first a wetter forest-type with bog characteristics, the second a dryer forest-type with heath characteristics.

*__Selective ground flora species__ (*sensu* Bunce (1982)) are those whose frequency in any TWINSPAN group was significantly greater (χ^2 goodness of fit, $p < 0.001$) than in all of the 1200 inventory plots taken together.

Population Trends of Nesting Glaucous-winged Gulls, *Larus glaucescens*, in the Southern Strait of Georgia, British Columbia

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Between 1986 and 1999, the number of nesting Glaucous-winged Gulls (*Larus glaucescens*) at fourteen breeding colonies declined by 31% (1610 nests) in the southern Strait of Georgia, British Columbia. Declines in the number of nesting pairs at surveyed colonies ranged between 6% and 81% with the smallest change occurring on the largest breeding colony in the study area. We suggest that Glaucous-winged Gull breeding population declines in the southern Strait of Georgia may be due to increased frequency of colony disturbance, in particular increased disturbance by Bald Eagles (*Haliaeetus leucocephalus*).

Key Words: Glaucous-winged Gulls, *Larus glaucescens*, declines, disturbance, British Columbia

The breeding population of Glaucous-winged Gulls (*Larus glaucescens*), like many populations of large gulls, increased in the Strait of Georgia during the 20th century (Drury 1973, 1974; Vermeer and Devito 1989). Glaucous-winged Gulls in this region increased from 6150 nesting pairs in 1960 to 13002 pairs in 1986 (Verbeek 1986; Vermeer and Devito 1989). This increase was thought to be the result of increased food abundance as this period corresponded with the increased utilization of landfill sites (Drent and Guiguet 1961; Vermeer 1963; Vermeer 1982; Butler et al. 1980).

The breeding population of Bald Eagles (*Haliaeetus leucocephalus*) also increased in the Strait of Georgia from 45 pairs in the 1970s to 97 pairs in 1987 (Trenholme and Campbell 1975; Vermeer et al. 1989). Bald Eagles prey on nesting Glaucous-winged Gulls (Butler et al. 1980; Vermeer et al. 1989; Vermeer and Devito 1989) and flush them from their nests allowing gulls and crows to depredate eggs and young (Drent et al. 1964; Verbeek 1982).

In this paper we document recent changes in the number of nesting pairs of Glaucous-winged Gulls at fourteen breeding colonies. We suggest that the recent decline in numbers of breeding Glaucous-winged Gulls in the southern Strait of Georgia is related to an increased frequency of disturbance at breeding colonies, and in particular disturbance by Bald Eagles.

Methods

Fourteen Glaucous-winged Gull colonies were censused in 1997 and 1999 (four colonies only in 1997; seven colonies only in 1999; and three small colonies in both years) in the southern Strait of Georgia, approximately 65 km south of Vancouver, British Columbia (49° 15′ N, 123° 07′ W) (Figure 1). The 14 colonies surveyed were selected because the sites coincided with other research initiatives; however, they are only a subset of the 76 islands and small islets used as nesting sites by Glaucous-winged Gulls in the Strait of Georgia (Vermeer and Devito 1989). Between 1 and 9 July 1997 and 1 and 25 June 1999 each colony was surveyed by one to four observers, depending on size of the colony, following survey methods outlined in Vermeer and Devito (1989). Briefly, colonies were censused by walking through the colony while counting nests. In large colonies we placed a small colored jellybean in each nest to ensure we did not re-count nests.

The daily presence or absence of Bald Eagles was recorded on Mandarte Island between 1 May and 31 July 1997. The presence of Bald Eagles was only recorded if we observed a disturbance of nesting gulls on the island. This differs from other studies, which also included Bald Eagles flying near Mandarte Island (Verbeek 1982).

Results and Discussion

A total of 3506 Glaucous-winged Gull nests were found at 14 colonies, an overall reduction of 1610 nests (31%) from 1986 (Table 1). The number of nesting pairs increased at a single colony, Grebe Islet, while nesting pair numbers dramatically decreased at the other 13 colonies. Reduction in nesting pairs ranged from 6% on Mandarte Island to 81% on Imrie Island. As a result, the distribution of

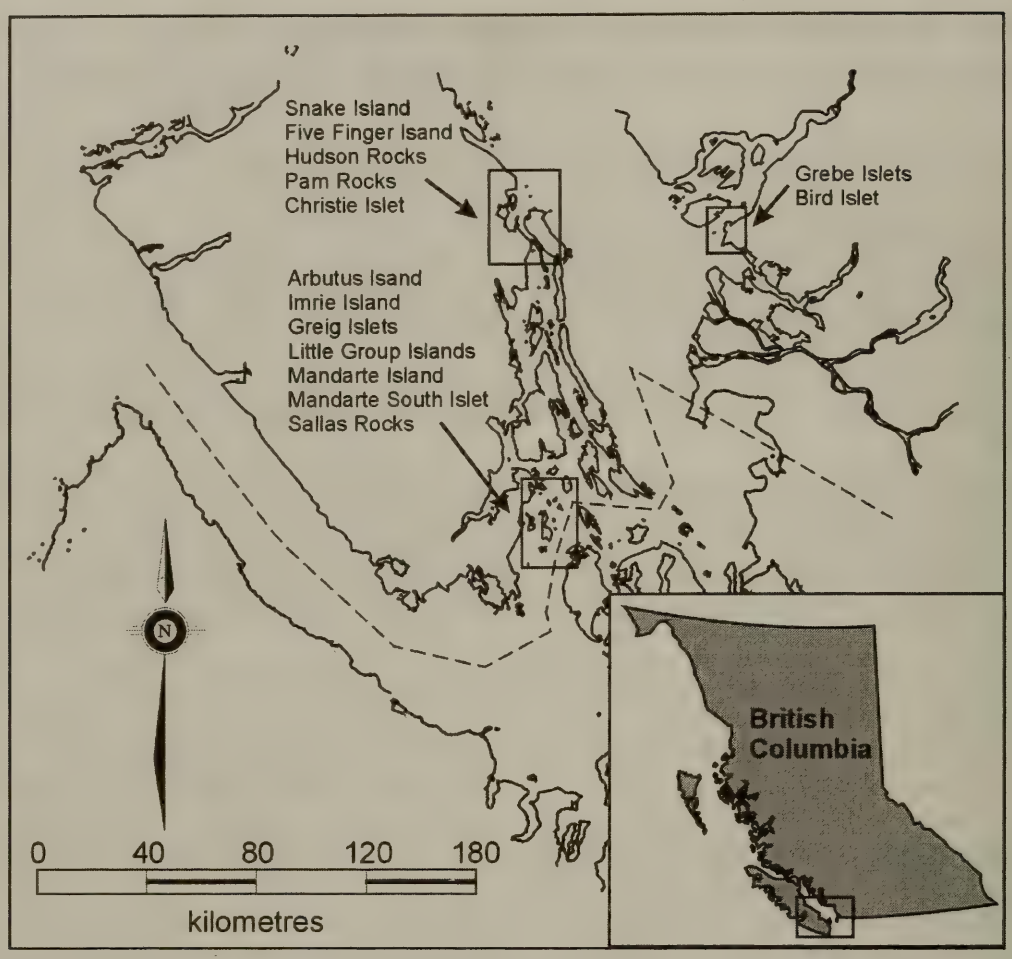

FIGURE 1. Location of the 14 Glaucous-winged Gull breeding colonies surveyed in the southern Strait of Georgia, British Columbia.

nesting Glaucous-winged Gulls shifted such that 61% of the nesting gulls were found on the largest breeding colony, Mandarte Island, in 1997 compared to 45% in 1986 (Table 1). This is the first reported decline in the number of nesting Glaucous-winged Gulls within the Strait of Georgia in almost four decades.

The decline in the number of nesting pairs of Glaucous-winged Gulls could be related to an increase in colony disturbances, and in particular increased disturbance by Bald Eagles. On Mandarte Island, Bald Eagles were observed flushing gulls on all days researchers were present on the island in 1997 (Table 2). In addition, the number of eagle disturbances of nesting gulls within each day, in 1997, ranged from 1 to 23 times, with up to six eagles on Mandarte Island at any one time. Colony disturbances during the nesting period result in egg and chick predation by Northwestern Crows and other Glaucous-winged Gulls (Verbeek 1982). On Mandarte Island, over 50 depredated gull eggs were found in a single crow cache in both 1996 and 1997. In addition to the increased number of breeding Bald Eagles in the Strait of Georgia, more than twice the numbers of eagles were observed in 1987 when compared to 1974 (Vermeer et al. 1989). An increase in the observed number of eagles on or near Mandarte Island was not detected until the late 1970s and early 80s. Since that time, eagle observations occurred almost every day during the gull breeding season.

Bald Eagles have negatively impacted other colonial nesting species in the Strait of Georgia. Increased Bald Eagle predation resulted in decreased breeding productivity of Great Blue Herons (*Ardea herodias fannini*) (Butler 1997; Vennesland 2000) and disturbances by Bald Eagles at Double-crested Cormorant colonies have caused delays in the onset of incubation by up to a month and a half (Sullivan 1998). However, the number of breeding Glaucous-winged Gulls only declined by 6% on Mandarte Island, a site with a high degree of Bald Eagle activity.

There are other possible sources of disturbance at gull colonies, including the presence of River Otters (*Lutra canadensis*) and humans. Otter trails and scat were found at all colonies during our surveys. River Otters prey upon Glaucous-winged Gulls (Foottit and Butler 1977; Verbeek and Morgan 1978) and were responsible for reproductive failure on Imrie Island in 1985 (Vermeer and Devito 1989). However, there is no current information on the

Table 1. Comparisons of the number of Glaucous-winged Gull nests from 1986 to 1997 or 1999 in the southern Strait of Georgia, British Columbia.

GWGU Colony	1986[1]	1997	1999	% Change from 1986 to 1999 (or 1997)
Arbutus Island	150	97	55	–63
Imrie Island	216	33	41	–81
Greig Islets	52	5	14	–73
Little Group Islands	6	3	ns	–50
Mandarte Island	2259	2124	ns	–6
Mandarte South Islet	104	97	ns	–7
Sallas Rocks	29	13	ns	–55
Snake Island	673	ns	204	–70
Five Finger Island	671	ns	288*	–57
Hudson Rocks	247	ns	122	–51
Pam Rocks	109	ns	25	–77
Christie Islet	454	ns	232*	–49
Bird Islet	38	ns	31	–18
Grebe Islets	108	ns	257	+138
Total	**5116**	**3506****	**–31**	

[1]1986 data from Vermeer et al. (1989); ns = not surveyed.
*Only 80% of the gull colony counted to avoid disturbance of nesting cormorants. Number estimated based on coverage of the colony.
**Sum of 1999 counts at 10 colonies and 1997 counts for 4 colonies with 1997 data only.

status of River Otter populations in the Strait of Georgia.

Human activities can also affect the number of disturbances at nesting colonies. Campfire pits and tent sites were found on many of the islands with nesting gulls. In addition, Verbeek (1982) detected an increase in the number of Bald Eagles flying over Mandarte Island on weekends and suggested that this was due to roosting eagles being disturbed by boaters at nearby islands.

Recent decreases in the breeding abundance of other large gulls in the northern hemisphere have been documented, including declines in breeding Herring Gulls (*Larus argentatus*) and Glaucous Gulls (*Larus hyperboreus*) (Gilchrist and Robertson 1999; Robertson et al. 2001). These declines have been attributed to decreased food supplies and habitat changes rather than to increased raptor populations.

We conclude that there has been an overall decline in the number of nesting Glaucous-winged Gulls at 14 colonies in the southern Strait of Georgia. We suggest that the observed decline in the numbers of breeding Glaucous-winged Gull pairs may be due to an increased frequency of disturbance by Bald Eagles, although there are many possible alternative explanations. We strongly recommend continued monitoring of the breeding Glaucous-winged Gull population in the Strait of Georgia.

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Table 2. The number of days observers were present on Mandarte Island (# Days) and the number of days Bald Eagles were observed on or flying by (Eagle Days) Mandarte Island, British Columbia.

	May			June			July			Total		
Year	# Days	Eagle	Days (%)	# Days	Eagle	Days (%)	# Days	Eagle	Days (%)	# Days	Eagle	Days (%)
1959[1]	31	13	(41)	30	6	(20)	31	2	(6)	91	21	(23)
1960[1]	31	12	(38)	30	7	(23)	31	4	(13)	91	23	(25)
1976[1]	31	14	(45)	30	6	(20)	29	2	(7)	90	22	(24)
1977[1]	31	17	(55)	30	14	(47)	29	12	(41)	90	43	(48)
1978[1]	31	14	(45)	30	9	(30)	31	7	(23)	91	30	(33)
1979[1]	31	20	(65)	30	21	(70)	22	5	(23)	83	46	(55)
1980[1]	31	21	(68)	30	24	(80)	21	15	(71)	82	60	(73)
1989	15	10	(66)	20	20	(100)	16	12	(75)	51	42	(82)
1996	30	30	(100)	30	30	(100)	22	17	(77)	82	77	(94)
1997	16	16	(100)	21	21	(100)	22	22	(100)	59	59	(100)

[1]Data from Verbeek (1982).

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Extralimital Occurrences of Ringed Seals, *Phoca hispida*, on Sable Island, Nova Scotia

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First records for the Ringed Seal, *Phoca hispida*, in Nova Scotia are documented. Most of these records are from Sable Island. These observations coincide with documented increases in extralimital records of other arctic seal species in the region. However, occurrences of vagrant Ringed Seals may not be due to the same factors responsible for recent increases in extralimital observations of Harp (*Pagophilus groenlandica*) and Hooded (*Cystophora cristata*) Seals in the Northwest Atlantic.

Key words: Distribution, Ringed Seal, *Phoca hispida*, Sable Island, Nova Scotia.

In the Northwest Atlantic during the 1990s there was a dramatic increase in the numbers of Harp (*Pagophilus groenlandica*) and Hooded (*Cystophora cristata*) seals observed outside their historic northern range (McAlpine and Walker 1990, 1999; Stevick and Fernald 1998; McAlpine et al. 1999a,b). This increase was observed on Sable Island, a 40 km long sand bar located about 250 km south-east of Halifax, Nova Scotia (Lucas and Daoust 2002). During this same period Ringed Seals, *Phoca hispida*, were recorded on the island for the first time. These observations provide the first confirmed records of the Ringed Seal for Nova Scotia. Here we document and comment on these observations.

The Ringed Seal is the most abundant seal in northern waters and is circumpolar in distribution. The species is widely distributed throughout the Canadian Arctic, in eastern Canadian marine waters occurring from Newfoundland and Labrador northward to the North Pole (Kingsley 1990; Reeves 1998). Peterson (1966) notes that this seal will sometimes venture south of the Strait of Belle Isle as far as La Tabitière, Quebec and South Brooks, Newfoundland, and Hannah (2000) reports that the Ringed Seal will move southward with the formation of ice down the north Shore of the Gulf of St. Lawrence as far as Harrington Harbour, Quebec. Both Peterson (1966) and Banfield (1974) plot an 1888 record from Manicaugau, well up the mouth of the St. Lawrence, as extralimital.

Ringed Seals occupy areas of stable, dense, sea-ice for most of the year. Although preferred breeding habitat appears to be land-fast ice in fiords and bays, this species is also widely distributed in drifting, offshore, pack ice, where some breeding has been observed (Reeves 1998; Wiig et al. 1999). Ringed Seals can remain in the Arctic year-round because of their ability to maintain breathing holes in very thick ice (Kingsley 1990). Although it has been assumed that adult Ringed Seals are largely sedentary (McLaren 1958), with young-of-the-year dispersing over distances up to several hundred kilometers, tagging studies in Greenland (Kapel et al. 1998) and in Arctic Canada (Smith 1987) have demonstrated dispersal distances for sub-adult Ringed Seals of more than 1000 km from site of release. Ridoux et al. (1998) note that extreme extralimital occurrences of arctic seals are often considered to be those of young and inexperienced animals. However, their observations suggest that juveniles have sufficient navigational skills to return to their usual habitat after traveling long distances. A juvenile Ringed Seal tagged and released at the western end of the English Channel in March 1995 was found among the stomach contents of a Greenland Shark (*Somniosus microcephalus*) in May 1996 north of Iceland. Assumming the seal was ingested by the shark in waters near Iceland, the Ringed Seal had traveled a minimum straight-line distance of 2600 km in five months (Ridoux et al. 1998)

There are no previously published reports of the Ringed Seal from Nova Scotia (Scott 1968) and currently no records of the Ringed Seal from New Brunswick. However, three Ringed Seals were reported from mainland Nova Scotia between 1991–1994 (T.Wimmer, personal communication to ZNL). Unfortunately, only minimal details for these mainland Nova Scotia records are available. One Ringed Seal was found at the mouth of the Sackville River, Bedford, in 1993. A second Ringed Seal, fat and healthy, but with several cuts on the body, was found at the same location on 2 March 1994. We have been unable to locate details on the third mainland Nova Scotia Ringed Seal. There are also recent observations from the eastern seaboard, exclusive of Nova Scotia, of Ringed Seals well south of their normal range. From 1989–2002 approxi-

mately 15 Ringed Seals have been recorded from Maine to New Jersey (B. L. Rubinstein, personal communication to ZNL), including two immature females found in New Jersey in late January 1990: one dead and one live, the latter approximately 85 cm in length (B. Schoelkopf, personal communication to ZNL).

Fourteen Ringed Seals have been reported from Sable Island since 1990 (Table 1). Identification of Ringed Seals was based on a pelage pattern showing distinct light-coloured rings on the dorsal surface of an otherwise dark-grey pelt, on relatively small body size and delicate head shape, and on comparison of skeletal features from seven of the animals (NBM 5851,5921,5932,5947,5948,5949,5950) with reference material in the New Brunswick Museum collection. In one specimen (NBM 5921) the characteristic pelage pattern was largely absent. Some light-coloured ring markings were present on the flanks, but otherwise the dorsal surface was a uniform grey.

Measured length is available for only six of the specimens found on Sable Island during 1990–2002; all were under 100 cm (Table 1). Ringed Seal pups in the eastern Canadian Arctic are born during early to mid-April at about 65 cm in length (Smith and Stirling 1975; McLaren 1993), and are suckled for about two months. Based on growth rates given in McLaren (1993), age of the six known-length specimens was probably 10 months for two, and likely 10 to 22 months for the other four. The carcass of a shark-killed seal (Figure 1), though very fresh, was extensively damaged and it was only possible to estimate length at roughly 100 cm or less. The remaining seven seals were less than 100 cm in length. Thus, all 14 Ringed Seals found from 1990–2002 were young animals.

Gut contents were examined in five specimens. The stomach of the female found 24 February 1998 contained a small amount of sand. The stomach of the male found on March 11 1998 contained a small amount of sand, one squid beak and two fragments of plastic, with no parasites and the colon was packed with a mix of dry solid feces and sand. The stomachs of the 14 December 1998, 20 January 2002, and 1 July 2002 animals were empty. King (1983) suggested that Ringed Seals may use suction in feeding, and thus may ingest sand when feeding near the bottom. The stomach of the January 1998 female killed at sea by a shark was empty, but the colon contained feces including many small unidentified otoliths.

Of the eight Ringed Seals for which blubber measurements are available, seven intact beached carcasses had mean dorsal and sternal blubber thicknesses of 9.1 mm (SD = 3.1 mm dorsal, SD = 3.9 mm sternal), whereas the one shark-killed Ringed Seal had dorsal and sternal blubber thickness of 45 mm and 30 mm, respectively. The sternal blubber thickness of the shark-killed Ringed Seal was within the range for the one- to four-year-old seals collected by McLaren (1958) in southwest Baffin Island and

Table 1. Ringed Seals observed on Sable Island 1990–2002.

Date	Sex	SL[1]	G	DB	SB	Observer	Comments
January 1990	m	—	—	—	—	Skip J. F. Young	live, healthy,
January 1992	—	—	—	—	—	G. Forbes, B. Beck	2 live, active; 1 on north, 1 on south side of island.
February 1995	—	—	—	—	—	Z. Lucas	live, active.
14 March 1996	m	—	—	—	—	Z. Lucas	live, small cuts on hind flippers.
14 January 1997	f	—	—	15	10	Z. Lucas	found dead (NBM 5947).
25 January 1997	m	79	55	6	8	Z. Lucas	found dead (NBM 5948).
24 February 1997	f	67	47	5	6	Z. Lucas	live, died 4 days later (NBM 5949)
11 April 1997	m	72	49	5	6	Z. Lucas	live, died 1 day later (NBM 5851)
5 January 1998	f	—	80	45	30	Z. Lucas	shark kill, Figure 1.
12 March 1998	m	—	—	—	—	Z. Lucas	live, very thin
14 December 1998	m	95	60	13	13	Z. Lucas	dead (NBM 5950)
20 January 2002	f	69	52	12	11	Z. Lucas	fresh dead (NBM 5921)
1 July 2002	m	~80	62	8	10	Z. Lucas	found dead, scavenged (NBM 5932)

[1]SL= standard length, G= girth, DB= dorsal blubber thickness, SB= sternal blubber thickness. SL and G recorded in cm; DB and SB recorded in mm.

FIGURE 1. Juvenile female Ringed Seal, shark-killed, Sable Island, Nova Scotia, 5 January 1998 (Z. Lucas photo).

northwest Foxe Basin during March to September. The shark-killed Ringed Seal was in better condition than the seals that died on the beach. Lucas and Daoust (2002) found that the dorsal and sternal regions of the blubber in intact carcasses of Harp and Hooded seals found on the beach were significantly thinner than in shark-killed animals. This indicates that while Harp and Hooded seals which come ashore are likely to be those animals in poor condition (McAlpine and Walker 1990), those that are killed by sharks may represent seals which are healthier and feeding at sea, and less likely to haul out. Thus, the greater blubber thickness and the presence of fish otoliths in the gut of the shark-killed Ringed Seal suggests that healthy individuals of this species may be found in waters of the Scotian Shelf.

While the dramatic increase in numbers of Harp and Hooded seals on Sable Island is well-documented (Lucas and Daoust 2002), the apparent increase in sightings of Ringed Seals may, in part, be the result of beach surveys for Harp and Hooded Seals carried out from 1995 to 1998. Eight of 14 Ringed Seals were found during these surveys, which were discontinued after spring 1998. Prior to these systematic surveys for Harp and Hooded seals, Ringed Seals may have been overlooked among the large numbers of juvenile Grey (*Halichoerus grypus*) and Harbour (*Phoca vitulina*) seals hauled out on Sable Island (Boulva and McLaren 1979; Mansfield and Beck 1977; Stobo and Zwanenburg 1990).

Although Fisheries and Oceans Canada have carried out research on seals on Sable Island during January–February and May–June of most years since 1965, the focus of these studies has been Grey and Harbour seals. If Ringed Seals were observed, these sightings were not recorded. Additionally, Ringed Seals resemble juvenile Harbour Seals in locomotion on land and superficially in appearance. Van Bree (1997) notes that even trained zoologists may have difficulty correctly identifying Ringed Seals. He suggests that increases in reports of arctic seals, including the Ringed Seal, on the western European continental coast should be attributed to previous misidentification, an increase in the number of naturalists, better identification manuals, and the creation of seal rehabilitation centers.

While the extralimital occurrences of Ringed Seals reported here coincide with a dramatic increase in numbers of Harp and Hooded seals on the Island, extralimital occurrences of Ringed Seals may not be due to the same factors. Reasons for the increase in numbers of extralimital occurrences of the more migratory Harp and Hooded seals remain speculative (McAlpine et al. 1999a; Lucas and Daoust 2002), but increases in Harp Seals have been linked to changes in environmental conditions (Lacoste and Stenson 2000).

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Science Centre, all generously shared information with us. The following institutions also provided assistance: the Nova Scotia Petroleum Directorate, EnCana Resources, and ExxonMobil Canada.

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Chromosome Numbers Determined from Canadian and Alaskan Material of Native and Naturalized Mustards, Brassicaceae (Cruciferae)

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Mulligan, Gerald A. 2002. Chromosome numbers determined from Canadian and Alaskan material of native and naturalized mustards, Brassicaceae (Cruciferae). Canadian Field-Naturalist 116(4): 611–622.

All herbarium specimens documenting chromosome numbers of 154 species and varieties of Canadian and Alaskan Brassicaceae (Cruciferae) were examined and their identity and nomenclature standardized. Included for each are the chromosome numbers, areas where the counted material was collected, publication references, voucher collectors and collection numbers, and the names of the herbarium repositories. All specimen-vouchered published records and a small number of previously unpublished chromosome number determinations are included.

Key Words: Mustards, Brassicaceae, Cruciferae, chromosome numbers, Canada, Alaska

Many chromosome numbers have been determined from Canadian and Alaskan material of native or naturalized mustards, Brassicaceae (Cruciferae), and the results published. These numbers were obtained either from material collected in nature or from plants cultivated from seed or roots taken from natural habitats. Voucher specimens were deposited in herbaria by most authors. Since different taxonomic treatments were used to identify the plants studied or, in a few instances, misidentifications occurred, I am standardizing the names of the taxa according to the taxonomy used in my recent *Key to the Brassicaceae (Cruciferae) of Canada and Alaska* (Mulligan 2002)*. I have been successful in obtaining for study virtually all of the chromosome vouchers. The most important exceptions are the herbarium vouchers for the many chromosome numbers published for Manitoba Brassicaeae by Áskell and Doris Löve (Löve and Löve 1975, 1982; Löve and Ritchie 1966). I have not seen annotated voucher specimens for any of their published chromosome numbers of Manitoba Brassicaceae. The authors stated that they had deposited vouchers, in either WIN or COLO. There are only a few unannotated, possible vouchers, in WIN and no Löve specimens in COLO. There are also no Löve Brassicaceae chromosome vouchers in CAN, DAO, MTJB, or MT, other possible repositories. Since the identifications cannot be checked and standardized without vouchers, I have, reluctantly, excluded most of their published chromosome numbers of Manitoba Brassicaceae from the following listing. For uniformity and to conserve space, all haploid numbers (n) are listed as somatic numbers (2n).

Literature references for any additional chromosome numbers, determined on Canadian or Alaskan material of native or naturalized Brassicaceae, would be appreciated. These can be sent to me at the above address or e-mailed to *mulligan4520@rogers.com.*

*see Documents Cited

Geographical Abbreviations

AK: Alaska
YT: Yukon
NT-M: Northwest Territories, Mackenzie District
N-F: Nunavut, Keewatin District
NF: Newfoundland and Labrador
PE: Prince Edward Island
NS: Nova Scotia
NB: New Brunswick
PQ: Québec
ON: Ontario
MB: Manitoba
SK: Saskatchewan
AB: Alberta
BC: British Columbia

Herbaria Cited Abbreviations

ALA: University of Alaska, Fairbanks, AK
ALTA: Botany Department, University of Alberta, AB
CAN: Botany Division, National Museum of Natural Sciences, Ottawa, ON [= Canadian Museum of Nature].
COLO: University of Colorado Museum, Boulder, Colorado
DAO: Vascular Plant Herbarium, Agriculture and Agri-Food Canada, Ottawa, ON
DS: Stanford University, San Francisco, California
GH: Botany Department, Harvard University, Cambridge, Massachusetts
HAM: Royal Botanical Gardens, Hamilton, ON
MT: Institut botanique, Université de Montréal, PQ
MTJB: Jardin botanique de Montréal, Montréal, PQ
QFA: Faculté des Sciences de l'agriculture et de l'alimentation, Université Laval, Sainte-Foy, PQ

QUE: Herbier du Québec, Complex scientifique, Sainte-Foy, PQ.
S: Botany Department, Swedish Museum of Natural History, Stockholm
UBC: Botany Department, University of British Columbia, Vancouver, BC
UPS: Botanical Museum, Uppsala University, Uppsala, Sweden
WIN: Botany Department, University of Manitoba, Winnipeg, MB

Systematic List

Alliaria petiolata (M. Bieb.) Cavara & Grande
2n = 42, ON, Grainger & MacLeod 4155 (DAO), Mulligan (1984) as *Alliaria officinalis.*
Alyssum alyssoides (L.) L.
2n = 32, BC, Mulligan & Mosquin 2684 (DAO), Mulligan (1964).
Alyssum desertorum Stapf
2n = 32, AB, Mulligan & Mosquin 2684 (DAO), Mulligan (1964).
Alyssum obovatum (C. A. Mey.) Turcz. (= *Alyssum americanum* Greene)
2n = 30, AK, Batten & Dawe 78-392 (ALA), Dawe & Murray (1981a) as *Alyssum americanum.*
Arabidopsis salsuginea (Pallas) O. E. Schulz (= *Thellungiella salsuginea* (Pallas) N. Busch)
2n = 14, YT, Calder & Gillett 25786 & 26489 (DAO) and Calder 28344 (DAO), all in Mulligan (1964) as *Thellungiella salsuginea.*
Arabidopsis thaliana (L.) Heynh.
2n = 10, ON, Grainger 4005 (DAO), Mulligan (1984).
Arabis alpina L.
2n = 16, PQ, Knowlton (GH), Rollins (1941); Cinq-Mars et al., 6 juil., 1960 (DAO), Mulligan (1964).
Arabis arenicola (Richardson ex Hook.) Gelert
2n = 16, PQ, Hedberg 3408b (UPS), Hedberg (1967); Lepage 39394 (DAO), Mosquin in Mulligan (1995).
Arabis caucasica Willd. (= *Arabis alpina* subsp. *caucasica* (Willd.) Briq.)
2n = 16, ON, Mulligan 2829 (DAO), Mulligan (1964) as *Arabis albida.*
Arabis columbiana Macoun
2n = 14, BC, Mosquin & Mulligan 4930 & 4937 (DAO), Mosquin in Mulligan (1995).
2n = 20+2B, BC, Calder & Spicer 33480 (DAO), Mulligan (1964) as *Arabis divaricarpa.*
Arabis divaricarpa var. *dacotica* (Greene) B. Boivin
2n = 14, MB, Löve & Löve 5373 (DAO, WIN), Löve & Löve (1975) as *Boechera divaricarpa.*
2n = 21, YT, Calder & Kukkonen 28067 (DAO), Mulligan (1964). BC, Calder & Gillett 26501 & 26648 (DAO), Mulligan (1964).
2n = 28, NT-M, Cody & Spicer 11451 (DAO), Mulligan (1964). MB, Mosquin & Mosquin 4904 & 4910 (DAO), Mosquin in Mulligan (1995). BC, Calder & Kukkonen 26749 (DAO), Mulligan (1964).
Arabis divaricarpa A. Nelson var. *divaricarpa*
2n = 13+2B, BC, Taylor et al. 3369 (DAO), Mulligan (1964).
2n = 14, MB, Löve & Löve 6026 (WIN), Löve & Löve (1982) as *Boechera divaricarpa.* SK, Taylor & Sherk 4708 (DAO), Taylor & Brockman (1966). AB, Mosquin et al. 4703 & 4751 (DAO), Mosquin in Mulligan (1995). BC, Taylor & Ferguson 3054 (DAO), Mulligan (1964).
2n = 21, AB, Mosquin & Benn 5183 (DAO), Mosquin in Mulligan (1995). BC, Calder & Gillett 26501 & 27052 (DAO), Mulligan (1964).
2n = 22, PQ, Gervais 95-33 (QFA), Gervais et al. (1999) as *Arabis holboellii.*
Arabis drummondii A. Gray
2n =14, YT, Calder & Kukkonen 28255 (DAO), Mulligan (1964). MB, Löve & Löve 6583 (WIN), Löve & Löve (1982) as *Boechera drummondii.* AB, Mosquin et al. 4706 & 4737 (DAO), Mosquin in Mulligan (1995). BC, Calder & MacKay 32750 (DAO), Mulligan (1964).
2n = 20, BC, Calder 28394 (DAO), Mulligan (1964).
2n = 21, BC, Mosquin et al. 4738 & 4755 (DAO), Mosquin in Mulligan (1995).
Arabis eschscholtziana (Hopkins) Rollins
2n = 64, BC, Calder et al. 34754 (DAO), Taylor & Mulligan (1968) as *Arabis hirsuta* subsp. *eschscholtziana.*
Arabis exilis A. Nelson
2n = 14, BC, Calder et al. 16531 & 16883 (DAO) and Calder & Spicer 33058 & 33427 (DAO), all in Mulligan (1964) as *Arabis pendulocarpa;* Gillett & Mitchell 3899 (DAO), Böcher (1969) as *Arabis pendulocarpa*; Taylor 6223 (UBC), Taylor & Taylor (1977), as *Arabis holboellii* var. *pendulocarpa.*

Arabis glabra (L.) Bernh. (= *Turritis glabra* L.)
2n = 12, PQ, Gillett 10569 (DAO), Mosquin in Mulligan (1995). ON, Mulligan 2836 (DAO), Mulligan (1964) as *Turritis glabra*. AB, Mosquin & Mosquin 4687 (DAO), Mosquin in Mulligan (1995). BC, Calder & Taylor 36526 (DAO), Taylor & Mulligan (1968).

Arabis hirsuta var. *pycnocarpa* (Hopkins) Rollins
2n = 32, NT-M, Cody & Spicer 11877 & 12249 (DAO), Mulligan (1964) as *Arabis hirsuta*. MB, Taylor & Sherk 4784 (DAO), Taylor & Brockman (1966) as *Arabis hirsuta*. AB, Mosquin et al. 4688, 4701 & 5184 (DAO), Mosquin in Mulligan (1995). BC, Mosquin & Mulligan 4933 (DAO), Mosquin in Mulligan (1995).

Arabis holboellii var. *consanguinea* (Greene) G. A. Mulligan
2n = 21, AB, Mosquin et al. 4696, 4705 & 5212 (DAO) and Mosquin 5201 (DAO), Mosquin in Mulligan (1995).

Arabis holboellii var. *retrofracta* (Graham) Rydb.
2n = 13+2B, MB, Boivin et al. 13209 (DAO), Mulligan (1964) as *Arabis holboellii*.
2n =14, MB, Gillett & Taylor 11693 (DAO), Mulligan (1964) as *Arabis holboellii*; Löve & Löve 6426 (WIN), Löve & Löve (1982) as *Boechera collinsia*; Mosquin & Mosquin 4911 (DAO), Mosquin in Mulligan (1995). SK, Boivin & Mosquin 10797 (DAO), Mulligan (1964) as *Arabis holboellii*; Mosquin & Mosquin 4914 & 4915 (DAO), Mosquin in Mulligan (1995). AB, Boivin & Perron 12626 (DAO), Mulligan (1964) as *Arabis holboellii*; Mosquin et al. 4454, 4460, 4683 & 4686 (DAO) and Calder & Gillett 26537 (DAO), all Mosquin in Mulligan (1995); Packer 6096 (ALTA), Packer (1964). BC, Calder et al. 26760, 26997 & 33417 (DAO), Mulligan (1964) as *Arabis holboellii*; Mosquin et al. 4454, 4460, 4929, 4935 & 4938 (DAO), Mosquin in Mulligan (1995).
2n = 14+1B, BC, Calder & Spicer 33794 (DAO), Mulligan (1964) as *Arabis holboellii*.
2n = 15, AB, Mosquin et al. 4735 (DAO), Mosquin in Mulligan (1995). BC, Mosquin & Mulligan 4932 (DAO), Mosquin in Mulligan (1995).
2n = 20+2B, SK, Mulligan 1049 (DAO), Mulligan (1964) as *Arabis holboellii*.
2n = ca.21, AB, Mosquin & Mulligan 4922 (DAO), Mosquin in Mulligan (1995). BC, Mosquin & Mosquin 4452 (DAO), Mosquin in Mulligan (1995).

Arabis holboellii var. *secunda* (Howell) Jepson
2n = 21, BC, Calder & Spicer 33722A (DAO), Mulligan (1964) as *Arabis holboellii*.

Arabis kamtschatica (Fisch. ex DC.) Ledeb. (= *Arabidopsis lyrata* subsp. *kamchatica* (Fisch. ex DC.) O'Kane & Al-Shehbaz)
2n = 32, AK, Drury 3380 (GH), Gaiser in Drury & Rollins (1952); Dawe (ALA), Dawe & Murray (1979) give the chromosome number of 2n = 16 for *Arabis lyrata* subsp. *kamchatica* but the voucher specimen in ALA clearly states that the number counted was 2n = 32. YT, R.T. Porsild 1275 (CAN), Mulligan & Porsild (1969a) as *Arabis lyrata* subsp. *kamchatica*; Porsild 1739 & 1788 (CAN), Mulligan & Porsild (1970) as *Arabis lyrata* subsp. *kamchatica*; Calder & Kukkonen 27785 (DAO), Mulligan (1964) as *Arabis lyrata*. BC, Calder & MacKay 30637 & 31670A (DAO) and Calder et al. 18457 (DAO), Mulligan (1964) as *Arabis lyrata*; Calder & Taylor 36389 (DAO), Taylor & Mulligan (1968) as *Arabis lyrata* subsp. *kamchatica*.

Arabis lemmonii S. Watson
2n = 14, AB, Calder & MacKay 32722A (DAO), Mulligan (1964). BC, Taylor et al. 3250 (DAO), Mulligan (1964).

Arabis lyallii S. Watson
2n = 21, AB, Calder & MacKay 32671 (DAO), Mulligan (1964). BC, Taylor & Ferguson 3815 (DAO), Mulligan (1964).

Arabis lyrata L. (= *Arabidopsis lyrata* (L.) O'Kane & Al-Shehbaz subsp. *lyrata*)
2n = 16, ON, Senn & Lindsay 5399 (DAO), Böcher (1969). SK, Boivin & Mosquin 10769 (DAO), Mulligan (1964). AB, Packer 80-29 (ALTA), Packer & Witkus (1982) as *Arabis lyrata* subsp. *kamchatica*.

Arabis microphylla Nutt. ex Torr. & Gray
2n = 14, BC, Taylor & Ferguson 2641 (DAO), Mulligan (1964).

Arabis petraea (L.) Lam. (= *Arabis media* N. Busch)
2n = 16, AK, Hogdon 8664 (GH), Rollins (1966) as *Arabis lyrata* var. *kamchatica*; Packer (ALTA), Johnson & Packer (1968) as *Arabis lyrata* subsp. *kamchatica*.

Arabis pinetorum Tidestr.
2n = 13+2B, MB, Boivin et al. 13209 (DAO), Mulligan (1964) as *Arabis holboellii*.
2n = 14, AK, Batten & Dawe 78-192A (ALA), Dawe & Murray (1979) as *Arabis holboellii*.
2n = 32, BC, Taylor 6231 (UBC), Taylor & Taylor (1977) as *Arabis sparsiflora* var. *columbiana*.

Athysanus pusillus (Hook.) Greene
2n = 26, BC, Calder & MacKay 30873 (DAO), Mulligan (unpublished).
Barbarea orthoceras Ledeb.
2n = 16, AK, Hatch 79 (ALA), Dawe & Murray (1979). YT, Porsild 546 (CAN), Mulligan & Porsild (1969a). BC, Calder & MacKay 31716 (DAO), Mulligan (1964); Calder et al. 34756 & 34847 (DAO), Taylor & Mulligan (1968).
Barbarea vulgaris (L.) W. T. Aiton
2n = 16, PQ, Gervais 71-030 (QUE), Gervais (1979). ON, Mulligan 2286 (DAO), Mulligan (1959); Grainger & MacLeod 4032, 4035, 4040, 4061, 4067, 4081, 4084, 4125, 4136 & 4172 (DAO), Mulligan & Grainger 4007 (DAO), Mulligan et al. 4018 & 4051 (DAO) and MacLeod et al. 4025 (DAO), all in Mulligan (1984).
Berteroa incana (L.) DC.
2n = 16, PQ, Cayouette 1720 (QUE), Gervais (1979). ON, Mulligan 2125 (DAO), Mulligan (1957).
Brassica juncea (L.) Czern.
2n = 36, AB, Mulligan 1483 (DAO), Mulligan (1959).
Brassica rapa L. (= *Brassica campestris* L.)
2n = 20, NB, Mulligan 1482 (DAO), Mulligan (1959) as *Brassica campestris*. PQ, Moreau (QUE), Gervais (1979). BC, Calder & Taylor 36051 (DAO), Taylor & Mulligan (1968) as *Brassica campestris*.
Braya glabella Richardson (= *Braya purpurascens* (R. Br.) Bunge)
2n = 56, AK, Packer 2098 (ALTA), Johnson & Packer (1968) as *Braya purpurascens*; Dawe & Lipkin 848 (ALA), Dawe & Murray (1979) as *Braya purpurascens*; Kelso 83-209a (ALA), Murray & Kelso (1997); Murray 3518 (DAO), Dawe (unpublished). N-F, Savile 4764A & 4707 (DAO), Mulligan (1965) as *Braya purpurascens*. BC, Calder & Kukkonen 27446 (DAO), Mulligan (1965) as *Braya purpurascens*.
Braya humilis (C. A. Mey.) B. L. Rob. (= *Neotorularia humilis* (Ledeb.) Hedge)
2n = 28, NT-M, Cody & Spicer 12128 (DAO), Mulligan (1965); Cody & Scotter 19268 (DAO), Mulligan et al. (1972). AB, Mosquin & Mosquin 4691(DAO), Mulligan (unpublished). BC, Taylor & Ferguson Z2427 (DAO), Mulligan (1965).
2n = 42, YT, Porsild 1701 (CAN), Mulligan & Porsild (1970). NT-M, Cody & Matte 9039 & 9334 (DAO), Cody & Gutteridge 7339 (DAO), Cody 13166 (DAO), Cody & Spicer 12259 (DAO) and Cody & Kehoe 12692, 12723 & 12732 (DAO), all in Mulligan (1965). N-F, Savile 4669 & 4763 (DAO), Mulligan (1965). AB, Calder & Spicer 33838 (DAO), Mulligan (1965). BC, Calder & Savile 11979 (DAO) and Calder & Kukkonen 27375 (DAO), both in Mulligan (1965).
2n = 56, NT-M, Cody & Gutteridge 7774 (DAO), Mulligan (1965). BC, Calder 28360 (DAO) and Taylor & Ferguson 3899 (DAO), both in Mulligan (1965).
Braya thorild-wulfii Ostenf.
2n = 28, N-F, Savile 4456, 4764B & 4740 (DAO) and Beschel 11070 (DAO), all in Mulligan (1965).
Cakile edentula (Bigelow) Hook. var. *edentula*
2n = 18, PQ, Bassett & Crompton 4266 (DAO), Mulligan (1964); Cody & Kemp 18194 (DAO), Mulligan (unpublished). BC, Calder & MacKay 31917 & 31959 (DAO), Mulligan (1964); Calder & Taylor 35336 (DAO),Taylor & Mulligan (1968).
Cakile edentula var. *lacustris* Fernald
2n = 18, ON, Gillett 10723 (DAO), Mulligan (1964) as *Cakile edentula*.
Cakile maritima Scop.
2n = 18, BC, Calder & Taylor 35430 (DAO), Taylor & Mulligan (1968).
Camelina microcarpa Andrz. ex DC.
2n = 40, AB, Mulligan 2108 (DAO), Mulligan (1957). SK, MacLeod 188 (DAO), Mulligan (1984).
Camelina sativa (L.) Crantz.
2n = 40, AB, Groh 2805 (DAO) and Frankton 1485 (DAO), both R. J. Moore (unpublished). BC, Groh 2997 (DAO) and Frankton 1486 (DAO), both Moore (unpublished).
Capsella bursa-pastoris (L.) Medik.
2n = 32, ON, Mulligan 1493 & 1523 (DAO), Mulligan (1957); Grainger & MacLeod 4002, 4037, 4045, 4062, 4090, 4107, 4120, 4124, 4182, 4184 & 4187 (DAO) and Mulligan et al. 4017 (DAO), all in Mulligan (1984). SK, MacLeod 44 (DAO), Mulligan (1984). BC, Calder & Taylor 35168 (DAO), Taylor & Mulligan (1968).
Cardamine angulata Hook.
2n = 40, BC, Calder et al. 34681 & 35030 (DAO) and Calder & Taylor 35497 (DAO), all Mulligan (1965).

Cardamine bellidifolia L.
2n = 16, AK, Packer 1832 (ALTA), Johnson & Packer (1968); McPherson & Galeski 72-9 (ALTA), Packer & McPherson (1974); Murray & Johnson 6310 (ALA), Dawe & Murray (1979). YT, Porsild 1264 (CAN), Mulligan & Porsild (1969a). N-F, Savile 4496 (DAO), Mulligan (1965). PQ, Trahan 92-43 (QFA), Gervais et al. (1997). AB, Packer, May 1959 (ALTA), Packer (1964). BC, Calder & MacKay 32513 (DAO) and Calder & Savile 36447 (DAO), both in Mulligan (1965).
Cardamine cocatenata (Michx.) O. Schwartz
2n = ca. 240, ON, Montgomery 195 (OAC), Montgomery (1955) under *Dentaria lanciniata*.
Cardamine digitata Richardson
2n = 28, AK, Thompson (GH), Rollins (1966); Packer 1838 (ALTA), Johnson & Packer (1968).
Cardamine diphylla (Michx.) A. W. Wood
2n = 96, ON, Montgomery 194 (OAC), Montgomery (1955) as *Dentaria diphylla*.
Cardamine hirsuta L.
2n = 16, BC, Calder et al. 16209 & 16457 (DAO), Mulligan (1965).
Cardamine microphylla Adams
2n = 28, AK, Kelso et al. 63 (ALA), Murray & Kelso (1997) as *Cardamine microphylla* subsp. *blaisdellii*.
2n = 64, NT-M, Calder 34009 (DAO), Mulligan (1965).
Cardamine occidentalis (S. Watson) Howell
2n = 64, BC, Calder & Taylor 35271 & 37465 (DAO), Mulligan (1965).
Cardamine oligosperma Nutt. ex Torr. & Gray
2n = 16, BC, Lindsay & Woodbury 647 (DAO) and Calder et al. 20895, 21073 & 22219A (DAO), all in Mulligan (1965).
Cardamine parviflora var. *arenicola* (Britton) O. E. Schulz
2n = 16, ON, Dore 19111 (DAO), Mulligan (1965) as *Cardamine parviflora*.
Cardamine pensylvanica Muhl ex Willd.
2n = 32, YT, Calder 26547 (DAO), Mulligan (1965). NB, Cunningham (DAO), Mulligan (1965). PQ, Dore 18633 (DAO), Mulligan (1965); Gagnon 96-183 (QFA), Gervais et al. (1999) as *Capsella bursa-pastoris*. BC, Calder & Taylor 37514 (DAO) and Calder et al. 19964 & 22580 (DAO), all in Mulligan (1965).
2n = 64, ON, Dore 18681 (DAO), Mulligan (1965).
Cardamine pratensis L.
2n = 80 to 100, AK, McPherson & Galeski 72-258 (ALTA), Packer & McPherson (1974).
Cardamine purpurea Cham. & Schlecht.
2n = ca.80, AK, Packer 2555 (ALTA), Johnson & Packer (1968).
Cardamine umbellata Greene
2n = 48, BC, Taylor & Calder 3751 (DAO), Calder & MacKay 31402 (DAO), Calder & Taylor 35966 & 36297 (DAO) and Calder et al. 22226, 34730 & 34755 (DAO), all in Mulligan (1965).
Cardaria chalepensis (L.) Hand.-Mazz.
2n = 80, SK, Mulligan 2408, 2409 & 2410 (DAO), Mulligan & Frankton (1962). AB, Mulligan 2432, 2433, 2441, 2442, 2443, 2444, 2446, 2447 & 2576 (DAO), Mulligan & Frankton (1962). BC, Mulligan 2402 (DAO), Mulligan & Frankton (1962).
Cardaria draba (L.) Desv.
2n = 64, AB, Mulligan 2435, 2436 & 2437 (DAO), Mulligan & Frankton (1962).
Cardaria pubescens (C. A. Mey.) Jarmol.
2n = 16, SK, Mulligan 2403, 2429, 2430 & 2431 (DAO), Mulligan & Frankton (1962). AB, Mulligan 2440 (DAO), Mulligan & Frankton (1962).
Cochlearia groenlandica L.
2n = 14, AK, Baldwin 1894 (GH), Rollins (1966); McPherson & Galeski 72-6 (ALTA), Packer & McPherson (1974) as *Cochlearia officinalis*; Kelso et al. 66 (ALA), Murray & Kelso (1997); Packer (ALTA), Johnson & Packer (1968). NT-M, Parmelee 2967 & 3203 (DAO), Mulligan (unpublished). N-F, Hedberg 3246 (UPS), Hedberg (1967); Mosquin & Martin 6444 (DAO), Mosquin & Hayley (1966) as *Cochlearia officinalis*. BC, Calder & Taylor 34727 & 35141 (DAO) and Calder et al. 22231 (DAO), all in Taylor & Mulligan (1968) as *Cochlearia officinalis*; Emrich 84 (DAO), Mulligan (unpublished).
Descurainia incana (Bernh. ex Fisch. & C. A. Mey.) Dorn (= *Descurainia richardsonii* (Sweet) O. E. Schulz)
2n = 14, YT, Gillett 4497 (DAO), Mulligan (1961a) as *Descurainia richardsonii*. PQ, Anderson 1220 (DAO), Mulligan (1961a) as *Descurainia richardsonii*. MB, Á. Löve 5216 (WIN), Löve & Löve (1982) as *Descurainia richardsonii*.

Descurainia incisa (Engelm. ex Gray) Britton var. *incisa*
2n = 14, YT, Packer 1500 (ALTA), Packer (1964) as *Descurainia sophioides*.
Descurainia pinnata var. *brachycarpa* (Richardson) Fernald
2n = 28, MB, Löve & Löve 5853 (WIN), Löve & Löve (1982) as *Descuria pinnata*. AB, Mulligan 2126 (DAO), Mulligan (1961a).
Descurainia sophia (L.) Webb.
2n = 28, SK, MacLeod 212 (DAO), Mulligan (1984). AB, Mulligan 2127 (DAO), Mulligan (1961a). BC, Calder & Taylor 36036 (DAO), Taylor & Mulligan (1968).
Descurainia sophioides (Fisch. ex Hook.) O. E. Schulz
2n = 14, YT, Calder 4216 (DAO), Mulligan (1961a). N-F, Kuc, July 25, 1968 (CAN), Mulligan & Porsild (1970).
Diplotaxis tenuifolia (L.) DC.
2n = 22, ON, Mulligan 2273 (DAO), Mulligan (1959).
Draba albertina Greene
2n = 24, NT-M, Cody 16443 (DAO), Mulligan (1975). AB, Mulligan et al. 3350 (DAO), Mulligan (1975). BC, Mulligan & Crompton 3611, 3612 & 3616 (DAO), in Mulligan (1975).
Draba alpina L.
2n = 80, AK, Packer et al. 72-16a (ALTA, photo DAO), Packer & McPherson (1974). N-F, Mulligan 3560, 3562 & 3563 (DAO), Mulligan (unpublished); Mulligan 3535 & 3542 (DAO) and Maycock & Op de Beeck 10493 (DAO), all in Mulligan (unpublished).
Draba arabisans Michx.
2n = ca.94, PQ, Gervais 95-184 (QFA), Gervais et al. (1999).
2n = 96, PQ, Mulligan 2917 (DAO), Mulligan & Beales 3147, 3196 & 3202 (DAO) and Cody & Kemp 18295 (DAO), all in Mulligan (1970a).
Draba aurea M. Vahl
2n = ca.72, PQ, Gervais 95-183B (QFA) and Gervais 95-188C (QFA), both in Gervais et al. (1997).
2n = 74, YT, Mulligan 3564 (DAO), Mulligan (unpublished). PQ, Dutilly & Lepage 39413 (DAO), Mulligan (1966); Mulligan & Beales 3201 (DAO), Mulligan (unpublished). BC, Mulligan & Crompton 3239 & 3251 (DAO), Mulligan (unpublished).
Draba borealis DC.
2n = 80, YT, Porsild 1276 (CAN) and Mulligan 3204 (DAO), Mulligan (1970a). AB, Calder 23936 (DAO), Mulligan (1966) as *Draba McCallae*; Mulligan & Mulligan 3379 & 3501 (DAO), Mulligan (1970a).
2n = 82, AB, Calder 37270 (DAO), Mulligan (1966) as *Draba McCallae*; Mulligan & Mulligan 3384 (DAO), Mulligan (unpublished).
Draba cana Rydb.
2n = 32, AK, Murray & Murray 2759 (DAO), Mulligan (1971a). YT, Calder & Kukkonen 28213 (DAO), Mulligan (1971a). NT-M, Kvale & Haggard 52 (DAO) and Calder 17244 (DAO), both in Mulligan (1971a). PQ, Cody & Mulligan 16325 (DAO) and Frankton & Frankton 2044 (DAO), both in Mulligan (1971a). AB, Mulligan 2918 (DAO), Mulligan & Crompton 3228 & 3261 (DAO) and Mulligan & Mulligan 3319A, 3470, 3486, 3499 & 3503A (DAO), all in Mulligan (1971a). BC, Calder & Kukkonen 26906 (DAO), Mulligan (1971a).
Draba cinerea Adams
2n = 48, AK, Kelso 84-381 (ALA), Murray & Kelso (1997). NT-M, Cody & Kehoe 12676A (DAO), Mulligan (1966) as *Draba lanceolata*; Scotter 7189 (DAO) and Cody 16058 (DAO), both in Mulligan (1971a). N-F, Savile 4667 (DAO), Mulligan (1971a).
Draba corymbosa R. Br. ex DC.
2n = ca.110 to 130, Mosquin & Martin 6472 (DAO), Mosquin & Hayley (1966) as *Draba bellii*.
2n = 144, NT-M, Parmelee 3205 (DAO) in Mulligan (1976). N-F, Parmelee & Seaborn 3919A (DAO) and Mulligan 3261(DAO), both in Mulligan (1976).
Draba crassifolia Graham
2n = 40, YT, Porsild 1952 (CAN), Mulligan 3510 (DAO) and Scotter 21025 (DAO), all in Mulligan (1975). AB, Calder & MacKay 32714 (DAO), Mulligan (1966); Mulligan & Mulligan 3397, 3444 & 3492 (DAO), Mulligan (1975). BC, Taylor & Ferguson 3760 (DAO), Mulligan (1966); Taylor et al. 5603 (DAO), Mulligan (1975).
Draba densifolia Nutt.
2n = 36, AB, Mulligan & Crompton 3245 (DAO), Mulligan (1976).*Draba fladnizensis* Wulf.
2n = 16, YT, Scotter 20707, 20862 & 20875 (DAO), Mulligan (1974a).

ıba glabella Pursh var. *glabella*
2n = 64, AK, Kelso 83-272 (ALA), Murray & Kelso (1997). YT, Porsild 227, 228 & 1677 (CAN), Mulligan (1970a). NT-M, Cody 15818 & 17627 (DAO) and Scotter 7181 (DAO), all in Mulligan (1970a); Kuc 410 (DAO) and Mulligan 3561 (DAO), Mulligan (unpublished). N-K, Maycock & Op de Beeck 9649, 9664, 10046, 10624, 10956 & 11057 (DAO) and Mulligan 3512, 3514, 3515, 3516, 3516a, 3519, 3520 (unusual, with creamy-yellow flowers), 3521, 3540, 3543 & 3547 (DAO), all in Mulligan (1970a). N-F, Mason 91 & 112 (DAO), Mulligan (1971a) as *Draba cinerea*. PQ, Mulligan & Beales 3144, 3145, 3148, 3150, 3166, 3179, 3182, 3183, 3184, 3190, 3195, 3199 & 3211 (DAO) and Lemieux et al. 3889 (DAO), all in Mulligan (1970a).
2n = 80, AK, Packer 1780b, 1926 & 1956 (ALTA), Johnson & Packer (1968) as *Draba hirta*. N-K, Maycock & Op de Beeck 9937 (DAO) and Mulligan 3533 (DAO), Mulligan (1970a).

Draba glabella var. *pycnosperma* (Fernald & Knowlton) G. A. Mulligan
2n = 64, PQ, Sherk & Cinq-Mars 480 (DAO), Mulligan (1970a) as *Draba glabella*.

Draba grandis Langsd. (= *Draba hyperborea* (L) Desv. and *Nesodraba grandis* (Langsd.) E. L. Greene)
2n = 36, BC, Calder & MacKay 31393 (DAO), Mulligan (1966) as *Draba hyperborea*.
2n = 38, BC, Calder & Taylor 36570 (DAO), Mulligan (1966) as *Draba hyperborea*.

Draba incana L.
2n = 32, PQ, Sherk & Cing-Mars 483 (DAO), Mulligan (1970a).

Draba incerta Payson
2n = 112, YT, Murray 1185 (ALA,DAO), Mulligan (1972). AB, Calder & MacKay 32710 (DAO), Mulligan (1966); Mulligan & Crompton 3235 & 3244 (DAO), Calder 37194, 37299 & 37307 (DAO) and Mulligan & Mulligan 3353, 3473, 3481, 3485 & 3495 (DAO), all in Mulligan (1972). BC, Taylor et al. 3324 (DAO), Mulligan (1966).

Draba juvenilis Kom. (= *Draba longipes* Raup)
2n = 64, YT, Porsild 1277 & 1278 (CAN) and Mulligan 3262 & 3263 (DAO), Mulligan (1970a) as *Draba longipes*. NT-M, Cody 16589 & 16616 (DAO), Mulligan (1970a) as *Draba longipes*.

Draba kananaskis G. A. Mulligan
2n = 64, AB, Mulligan & Mulligan 3477 & 3548 (DAO), Mulligan (1970b).

Draba lonchocarpa Rydb. var. *lonchocarpa*
2n = 16, YT, Porsild 1698 (CAN), Mulligan (1974a). AB, Calder & MacKay 32710A (DAO), Mulligan & Mulligan 3474 & 3488 (DAO) and Mulligan & Crompton 3219 (DAO), all in Mulligan (1974a). BC, Calder & Kukkonen 27216 (DAO), Calder & MacKay 32771 (DAO) and Mulligan & Mulligan 3459 (DAO), all in Mulligan (1974a).

Draba lonchocarpa var. *vestita* O. E. Schulz
2n = 16, BC, Calder & Taylor 36382 (DAO), Mulligan (1974a).

Draba macounii O. E. Schulz
2n = 64, BC, Mulligan & Mulligan 3450 (DAO) and Calder & Kukkonen 27184 (DAO), Mulligan (1976).

Draba murrayi G. A. Mulligan
2n = 48, AK, Batten & Dawe 78-291 (ALA, photo DAO), Dawe & Murray (1981b).

Draba nemorosa L.
2n = 16, ON, Frankton 1915 (DAO) and Cody 18059 (DAO), both in Mulligan (1975). MB, Boivin & Löve 5404 (WIN), Löve & Löve (1982). SK, Mulligan 2835 (DAO) and Sherk & Taylor 134 (DAO), both in Mulligan (1975). AB, Packer, June 2, 1962 (ALTA), Packer (1964); Mosquin & Mosquin 4685 (DAO), Mulligan (1966); Mulligan & Crompton 3223 (DAO), Mulligan (1975).

Draba nivalis Liljebl.
2n = 16, AK, Packer, 12 Aug., 1962 (ALTA), Johnson & Packer (1968); Dawe 79-52 (ALA), Dawe & Murray (1980); Batten et al. 78-67 (ALA), Dawe & Murray (1981b) as *Draba lactea*. YT, Porsild 464 (CAN), Mulligan & Porsild (1969a). NT-M, Cody 17628 (DAO) and Scotter 6462a (DAO), both in Mulligan (1974a). N-F, Parmelee & Seaborne 4027 & 4177 (DAO), Mulligan (1974a). N-K, Whitton, Aug. 30, 1967 (DAO) and Maycock & Op de Beeck 9832, 10805, 11014 & 11073 (DAO), all in Mulligan (1974a). BC, Taylor 5713 (DAO), Mulligan (1974a).

Draba norvegica R. Br. ex DC.
2n = 48, NT-M, Cody 16016 (DAO), Mulligan & Cody (1968). N-K, Maycock & Op de Beeck 10165, 10405, 10500B, 10535 & 10934 (DAO), all in Mulligan (1970a). PQ, Trahan 92-92A (QFA), Gervais et al. (1997) under *Draba clivicola*.

Draba oblongata R. Br. ex DC. (= *Draba groenlandica* E. Ekman)
2n = 64, N-F, Parmelee 2089 (DAO), Mulligan (1971a) as *Draba groenlandica*.

Draba ogilviensis Hultén
2n = 16, YT, Porsild 141 (CAN), Mulligan & Porsild (1969b) as *Draba sibirica*.
Draba oligosperma Hook.
2n = 64, YT, Porsild 1336 (CAN), Mulligan (1972). AB, Mulligan & Crompton 3217, 3221, 3242, 3243, 3246 & 3255 (DAO) and Mulligan & Mulligan 3471(DAO), all in Mulligan (1972).
Draba pauciflora R. Br. (= *Draba adamsii* Ledeb.)
2n = 32, AK, Packer et al. 72-80 (ALTA), Packer & McPherson (1974) as *Draba adamsii*; Packer et al. 72-16b & 72-212 (ALTA, photos DAO), Mulligan (1974b) as *Draba adamsii*.
Draba paysonii J. F. Macbr.
2n = 42, AB, Mulligan & Crompton 3230 & 3249 (DAO) and Mulligan & Mulligan 3333 (DAO), Mulligan (1971b).
Draba porsildii G. A. Mulligan
2n = 32, YT, Scotter, Aug. 4,1972 (DAO), Mulligan (1974b). AB, Mulligan & Crompton 3220 (DAO), Calder & Kukkonen 27184A (DAO), Calder 37299a (DAO) and Mulligan & Mulligan 3472 & 3491 (DAO), all in Mulligan (1974a).
Draba praealta Greene
2n = 56, AB, Calder 37269 (DAO), Mulligan (1966). BC, Taylor & Ferguson 3187 (DAO), Mulligan (1966).
Draba reptans Lam.
2n = 30, SK, Boivin 13494 (DAO), Mulligan (1966).
Draba ruaxes Payson & H. St. John
2n = ca.72, YT, Murray & Murray 1343 (ALA,DAO), Mulligan (1971b).
Draba scotteri G. A. Mulligan
2n = 96, YT, Scotter 21041A (DAO), Mulligan (1979).
Draba stenoloba Ledeb.
2n = 40, AB, Scotter 13993 (DAO), Mulligan 3558 (DAO) and Mulligan & Mulligan 3498 (DAO), all in Mulligan (1975).
Draba subcapitata Simmons
2n = 16, N-F, Mason 69 (DAO) and Mulligan 3511 (DAO), Mulligan (1974a).
Draba ventosa A. Gray
2n = 36, AB, Mulligan & Mulligan 3489 (DAO), Mulligan (1971b). BC, Mulligan & Mulligan 3466 (DAO), Mulligan (1971b).
Draba verna L.
2n = 39, BC, Calder & Spicer 33089 (DAO), Mulligan (1966).
Draba wahlenbergii Hartm. (= *Draba lactea* of most authors)
2n = 48, AK, Packer et al. 72-1 (ALTA), Packer & McPherson (1974) as *Draba lactea*; Young 1380 (DAO) and Murray & Murray 2267 (ALA, DAO), both in Mulligan (1974a) as *Draba lactea*; the voucher specimens for the 2n = 16 count listed in Dawe & Murray (1981b), Batten et al. 78-67 (ALA), are all specimens of *Draba nivalis*. N-F, Parmelee & Seaborne 3760 & 3922 (DAO), Mulligan (1974a) for *Draba lactea*. N-K, Maycock & Op de Beeck 10335, 10482 &10751 (DAO), Mulligan 3526, 3544 & 3559 (DAO) and Morisette 70/156 (DAO), all in Mulligan (1974a) as *Draba lactea*.
Erucastrum gallicum (Willd.) O. E. Schulz
2n = 30, MB, Mulligan 2128 (DAO), Mulligan (1957). SK, MacLeod 168 (DAO), Mulligan (1984).
Erysimum angustatum Rydb.
2n = 36, AK, Batten & Dawe 78-220 (ALA), Dawe & Murray (1981b).
Erysimum arenicola S. Watson
2n = 36, BC, Calder & MacKay 32024 & 32184 (DAO), Mulligan (1966) as *Erysimum capitatum*.
Erysimum cheiranthoides L.
2n = 16, PQ, Gervais 71-341 (QUE), Gervais (1981). ON, Mulligan 1444 (DAO), Mulligan (1957); Mulligan & Grainger 4005 (DAO), Mulligan (1984). BC, Calder & Taylor 36026 (DAO), Taylor & Mulligan (1968).
Erysimum coarctatum Fernald
2n = 54, YT, Martin 24 & 40 (DAO), Calder & Kukkonen 27983 & 28014 (DAO), Calder 28352 (DAO) and Cody 12564 (DAO), all in Mulligan (1966) as *Erysimum inconspicuum*.
Erysimum hieraciifolium L.
2n = 48, ON, Mulligan & Rae 2137 (DAO), Mulligan (1959); Mulligan & Mulligan 3103 & 3106, meiosis irregular and 4, 5, or 6 microspores (DAO), Mulligan & Frankton (1967).
Erysimum inconspicuum (S. Watson) MacMill.
2n = 81, ON, Dore & Gillett 17515 (DAO) and Garton 6807 (DAO), both in Mulligan (1966). MB, Bassett 3580 (DAO), Mulligan (1966). AB, Jenkins 7954 (DAO), Mulligan (1966). BC, Mosquin 2678 & 2681 (DAO), Mulligan (1966).

Erysimum pallasii (Pursh) Fernald
2n = 24, YT, Calder 34130 & 34295 (DAO), Mulligan (1966); Packer 1385 (ALTA), Packer (1964). N-F, Mosquin & Martin 6405 (DAO), Mosquin & Hayley (1966).
2n = 28, YT, Porsild 55 (CAN), Mulligan & Porsild (1969a).
2n = 36, AK, Thompson (DS), Rollins (1966).
2n = 42, AK, Hultèn (S), Hedberg (1967).
Eutrema edwardsii R. Br.
2n = 28, AK, Packer (ALTA), Johnson & Packer (1968); Packer et al. 72-66 (ALTA), Packer & McPherson (1974). N-F, Savile 4724 (DAO), Mulligan (1964); Hedberg 3305 (UPS), Hedberg (1967).
2n = 42, N-F, Parmelee 2200a (DAO), Mulligan (1964).
Halimolobos mollis (Hook.) Rollins
2n = 16, YT, Calder & Gillett 24966 (DAO), Mulligan (1964).
2n = 20, AK, Batten & Dawe 78-384 (ALA), Dawe & Murray (1981a).
Hesperis matronalis L.
2n = 24, ON, Cody 21126 (DAO), Mulligan (1984).
Lepidium bourgeauanum Thell.
2n = 32, NT-M, Mulligan 2418 & 2419 (DAO), Mulligan (1961a,b). PQ, Mulligan 2423 (DAO), Mulligan (1961a,b).
Lepidium campestre (L.) R. Br.
2n = 16, ON, Mulligan 1499 (DAO), Mulligan (1957). SK, Mulligan 2219 (DAO), Mulligan (1957). BC, Calder & Taylor 36012 (DAO), Taylor & Mulligan (1968).
Lepidium densiflorum Schrad. var. *densiflorum*
2n = 32, PQ, Gervais 77-101 (QUE), Gervais (1979). ON, Mulligan 1528 (DAO), Mulligan (1957); Mulligan 2413 (DAO), Mulligan (1961a,b). SK, MacLeod 233 (DAO), Mulligan (1984).
Lepidium densiflorum var. *elongatum* (Rydb.) Thell.
2n = 32, BC, Mulligan 2422 (DAO), Mulligan (1961a,b).
Lepidium densiflorum var. *macrocarpum* G. A. Mulligan
2n = 32, BC, Mulligan 2416 (DAO), Mulligan (1961a,b).
Lepidium latifolium L.
2n = 24, AB, Mulligan 2147 (DAO), Mulligan (1957).
Lepidium perfoliatum L.
2n = 16, AB, Mulligan 1577 (DAO), Mulligan (1957). BC, Stein 4302 (UBC), Taylor & Taylor (1977).
Lepidium ramosissimum A. Nelson
2n = 64, NT-M, Mulligan 2417 (DAO), Mulligan (1961a,b). SK, MacLeod 27 (DAO), Mulligan (1984). AB, Mulligan 2129 (DAO), Mulligan (1957); Mulligan 2424 (DAO), Mulligan (1961a,b).
Lepidium virginicum L.
2n = 32, ON, Mulligan 2420 (DAO), Mulligan (1961a,b). BC, Mulligan 2421 (DAO), Mulligan (1961a,b).
Lesquerella arctica (Wormsk. ex Hornem.) S. Watson
2n = 60, AK, Murray 6727 (ALA), Dawe & Murray (1981a). N-F, Savile 4459 (DAO) and Bruggeman 4459 (DAO), both Mulligan in Rollins & Shaw (1973).
Lesquerella arenosa (Richardson) Rydb.
2n = 10, SK, Mulligan & Mosquin 4913 (DAO), Mulligan in Rollins & Shaw (1973). AB, Mulligan & Mosquin 2670 (DAO), Mulligan in Rollins & Shaw (1973).
Lesquerella calderi G. A. Mulligan & A. Porsild
2n = 20, YT, Porsild 1095 (CAN) and Mulligan 3212 & 3213 (DAO), Mulligan & Porsild (1969b).
Lesquerella douglasii S. Watson
2n = 10, BC, Mulligan & Mosquin 2683 (DAO) and Calder & Spicer 32860 (DAO), Mulligan in Rollins & Shaw (1973).
Nasturtium crystallinum (Rollins) G. A. Mulligan
2n = 32, NT-M, Cody 14789 (DAO), Mulligan & Cody (1995).
Nasturtium microphyllum Boenn. ex Rchb.
2n = 64, PE, Erskine 2487 (DAO), Mulligan (1964). ON, Mulligan & Moore 2651 (DAO), Mulligan (1964); Cody 21136 (DAO), Mulligan (1984).
Neslia paniculata (L.) Desv.
2n = 14, ON, Mulligan 1485 (DAO), Mulligan (1957). BC, Calder & Taylor 36018 (DAO), Taylor & Mulligan (1968).
Parrya arctica R. Br.
2n = 14, N-F, Mosquin & Martin 6471 (DAO), Mosquin & Hayley (1966).
2n = ca.21, N-F, Mosquin & Martin 6401 (DAO), Mosquin & Hayley (1966).

Parrya nudicaulis (L.) Regel
2n = 14, N-F, Sørensen (UPS), Hedberg (1964).
2n = 28, YT, Porsild 1683 (CAN), Mulligan & Porsild (1970).There is no voucher specimen for the count of 2n = 28 in Johnson & Packer (1968) according to J. G. Packer in personal correspondence, 13 June 2001.
Physaria didymocarpa (Hook.) A. Gray
2n = 16, AB, Calder 23921 (DAO) and Mulligan & Mosquin 2669 & 2672 (DAO), all in Mulligan (1968).
Raphanus raphanistrum L.
2n = 18, NB, Mulligan 2555 (DAO), Mulligan (1961a).
Rorippa amphibia (L.) Besser
2n = 32, PQ, Gervais 96-17 (QFA), Gervais et al. (1999) as *Rorippa sylvestris*.
Rorippa barbareifolia (DC.) Kitagawa
2n = 16, AK, Hatch 79 (ALA), Dawe & Murray (1979). YT, Porsild 547B & 1209 (CAN), Mulligan & Porsild (1968); Porsild 1722 (CAN), Mulligan & Porsild (1970).
Rorippa curvipes Greene var. *curvipes*
2n = 16, BC, Calder & Taylor 35945 (DAO), Taylor & Mulligan (1968) as *Rorippa islandica*.
Rorippa curvisiliqua (Hook.) Bessey ex Britton
2n = 16, BC, Molyneux 223 (DAO), Mulligan (1964).
Rorippa palustris (L.) Besser
2n = 32, AK, Murray & Johnson 6309 (ALA), Dawe & Murray (1980). YT, Calder & Kukkonen 28028 & 28299 (DAO), Mulligan (1964) as *Rorippa islandica*. NS, Smith et al. 15009 (DAO), Mulligan (1964) as *Rorippa islandica*. PQ, Rolland-Germain 7012 (DAO), Mulligan (1964) as *Rorippa islandica*. MB, Bassett & Kemp 3536 (DAO), Mulligan (1964) as *Rorippa islandica*; Löve & Löve 5486 & 5820 (WIN), Löve & Löve (1982). SK, Selleck 303 (DAO), Mulligan (1964) as *Rorippa islandica*; MacLeod 103 (DAO), Mulligan (1984). BC, Eastham 566 (DAO), Mulligan (1964) as *Rorippa islandica*.
Rorippa sylvestris (L.) Besser
2n = 32, PQ, Mulligan 2527 (DAO), Mulligan & Munro (1984). ON, Mulligan 2537, 2538 & 2580 (DAO), Mulligan & Munro (1984).
2n = 40, ON, Mulligan 2533, 2534 & 2535 (DAO), Mulligan & Munro (1984). BC, Mulligan 2539 (DAO), Mulligan & Munro (1984).
2n = 48, NB, Mulligan, 2515, 2516, 2517 & 2518 (DAO), Mulligan & Munro (1984). PQ, Mulligan 2509, 2510, 2514, 2519, 2521, 2522, 2523, 2524, 2525 , 2528 & 2530 (DAO), Mulligan & Munro (1984). ON, Mulligan 2501, 2505, 2506, 2508, 2511, 2512, 2531, 2532 & 2536 (DAO), Mulligan & Munro (1984). AB, Mulligan 2270 (DAO), Mulligan & Munro (1984). BC, Mulligan 2268, 2278 & 2279 (DAO), Mulligan & Munro (1984).
Schoenocrambe linifolia (Nutt.) Greene
2n = 14, BC, Taylor 6228 (UBC), Taylor & Taylor (1977).
Sinapis arvensis L.
2n = 18, ON, Grainger & MacLeod 4177, 4228, 4324 & 4352 (DAO) and MacLeod 4834 (DAO), all in Mulligan (1984). MB, Warwick et al. 8154, 8221 & 8224 (DAO), Warwick et al. (1994). SK, MacLeod 18 & 99 (DAO), Mulligan (1984). AB, Warwick et al. 8225 & 8226 (DAO), Warwick et al. (1994). BC, Calder & Taylor 36014 (DAO), Taylor & Mulligan (1968).
Sisymbrium altissimum L.
2n = 14, ON, Mulligan 1471 (DAO), Mulligan (1961a). SK, MacLeod 89 & 174 (DAO), Mulligan (1984). BC, Calder & Taylor 36043 (DAO), Taylor & Mulligan (1968).
Sisymbrium loeselii L.
2n = 14, AB, Mulligan 2130 (DAO), Mulligan (1957).
Sisymbrium officinale (L.) Scop.
2n = 14, BC, Calder & Taylor 35912 (DAO), Taylor & Mulligan (1968).
Smelowskia borealis (Greene) Drury & Rollins
2n = 12, AK, Murie (CAN), Gaiser in Drury & Rollins (1952); Batten 75-455 (ALA), Dawe & Murray (1979); Rice (ALA), Dawe & Murray (1981a); Parker 1734 (ALA), Murray & Kelso (1997).
Smelowskia calycina (Stephan ex Willd.) C. A. Mey. var. *americana* (Regel & Herder) Drury & Rollins
2n = 22, AB, Calder 37261 (DAO), Brockman (unpublished); Mulligan & Mosquin 2675 (DAO) and Mulligan & Crompton 3247 (DAO), both Mulligan (unpublished); Packer 2750 (ALTA), Packer (1968).
Smelowskia calycina var. *porsildii* Drury & Rollins
2n = 22, AK, Packer 1923 (ALTA), Johnson & Packer (1968) as *Smelowskia calycina* var. *integrifolia*. The vouchers listed in Dawe & Murray (1979) for *Smelowskia calycina* subsp. *integrifolia* var. *porsildii*, Young 7519 & 7520, with the chromosome number of 2n = 22, are not in ALA as was indicated in the paper (Alan Batten in personal correspondence, May 25, 2001).

Smelowskia media (Drury & Rollins) G. A. Mulligan
2n = 12, AK, Murray 6901 & 6903 (ALA), Dawe & Murray (1981b) as *Smelowskia calycina* subsp. *media*. YT, Calder 34367 & 34286 (DAO), Mulligan (unpublished).
Smelowskia pyriformis Drury & Rollins
2n = 12, AK, Parker 1256 (ALA), Murray & Kelso (1997).
Subularia aquatica var. *americana* (G. A. Mulligan & Calder) B. Boivin
2n = ca.28, PQ, Lepage 33378 (DAO), Mulligan & Calder (1964).
2n = 30, BC, Calder & Taylor 23653 (DAO), Taylor & Mulligan (1968).
Thlaspi arcticum A. Porsild
2n = 14, AK, Murray 6199 (ALA), Dawe & Murray (1981b).
Thlaspi arvense L.
2n = 14, ON, Mulligan 1476 (DAO), Mulligan (1957); Pringle 797 (HAM), Pringle (1969); Mulligan & Grainger 4009 (DAO), Mulligan (1984). SK, MacLeod 56 (DAO), Mulligan (1984). AB, Mulligan 1495 (DAO), Mulligan (1957).

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Weedy Introduced Mustards (Brassicaceae) of Canada

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A list of all 9 of the weedy introduced mustards of Canada is provided, along with information on their introduction, origin, spread, distribution, abundance, and habitats in Canada. Chromosome numbers determined for 41 from Canadian material are included.

Key Words. Introduced weedy mustards, Brassicaceae, distributions, habitats, chromosome numbers, Canada

Canadian weeds are plants that are preprogrammed to colonize the many open and disturbed habitats created and maintained by deforestation, agriculture, settlements, and a network of railway lines and roads. Some of these weedy colonizers are native plants that previously only occurred in naturally disturbed habitats, but the most aggressive are introduced plants that have evolved as the result of a long association with human activities in the Old World. In addition, many of these introduced colonizers have left their competitors, pests, and parasites behind. Some of the most successful weedy colonizers in Canada are plants of the mustard family *(Brassicaceae)*. A few of these, such as Bird Rape (*Brassica rapa* L.) and wild and cultivated radishes (*Raphanus* species), have even evolved both weedy and cultivated strains during their long association with humans. The most successful colonizing mustards are generally autogamous (produce abundant seed by self-fertilization within the same plant), apomictic (produce abundant seed without the ovaries being fertilized), or have either a strong vegetative means of reproduction or are common contaminants in crop seed. Colonization by weeds is completely dependent on the availability of the many disturbed habitats that we have created and continue to maintain. Humans are, in fact, mainly responsible for creating and maintaining the habitats that are necessary for the survival of the very plants that we are most anxious to control or eliminate.

This paper provides a listing of the weedy introduced mustards of Canada, and information on their origin, introduction, spread, distribution, abundance, and habitats. Included are the chromosome numbers that have been determined from Canadian material. Much of the information included here has resulted from data obtained during two of my recent studies: *Key to the Brassicaceae (Cruciferae) of Canada and Alaska* (Mulligan 2002*) and *Chromosome numbers determined from Canadian and Alaskan material of native and naturalized mustards Brassiceae (Cruciferae)* (Mulligan 2002).

*see Documents Cited

Abbreviations

AK: Alaska
YT: Yukon
NT-M: Northwest Territories- Mackenzie District
N-K: Nunavut- Keewatin District
N-K: Nunavut- Franklin District
NF: Newfoundland and Labrador
PE: Prince Edward Island
NS: Nova Scotia
NB: New Brunswick
PQ: Québec
ON: Ontario
MB: Manitoba
SK: Saskatchewan
AB: Alberta
BC: British Columbia

Systematic List

Alliaria petiolata (M.Bieb.) Cavara & Grande (= *Alliaria officinalis* Andrz. ex M. Bieb.) — Garlic Mustard; Alliaire officinale

Self-incompatible biennial. Introduced from Europe for use as a medicinal and salad plant. First collected at Moss Park, Toronto, ON, by J. Fletcher in 1874. Shaded and semi-shaded habitats in NB, PQ, ON, and BC; sporadic except in southern ON. Disagreeable flavor in milk from cows eating garlic mustard. See Cavers et al. (1979). 2n = 42, ON (Mulligan 1984).

Alyssum alyssoides (L.) L. — Small Alyssum; Alysson à calices persistants

Self-compatible, autogamous, annual or winter annual, introduced from Eurasia. First collected by W. Scott at Lincoln, ON, in 1896. Roadsides, railway beds, waste places, ballast, and other disturbed habitats in NF, PQ, ON, MB, AB, and BC; most common in southern ON and southeastern BC. 2n = 32 (Mulligan 1964).

Alyssum desertorum Stapf — Yellow Alyssum; Alysson de déserts

Self-compatible, autogamous, annual, introduced from eastern Europe and western Asia. First

collected on a railroad grade at Mortlack, SK, by J. H. Hudson in 1955. Prairie, grain elevators, railway beds, roadsides, and waste places in southern SK, southern AB, and southeastern and southcentral BC. Abundant on sheep rangelands in Rocky Mountain and Great Basin regions of the United States (Rollins 1981). 2n = 32, AB (Mulligan 1964).

Alyssum murale Waldst. & Kit. — Yellow-tuft

Caespitose perennial. Ornamental, native of Europe, that is a rare escape from cultivation or persists at old garden sites in PQ, ON, AB, and BC. First collected at Lambton, ON, by H. N. Racicot in 1947.

Alyssum saxitale L. — Golden-tuft

Perennial, introduced from Europe. Frequently grown as an ornamental. The only specimen seen was collected in waste ground at Ste-Anne-de-la-Pocatière, PQ, by L. Cinq-Mars in 1967. It may not persist in nature.

Arabidopsis thaliana (L.) Heynh. — Mouse-ear-cress; Arabette des dames

Self-compatible, autogamous, annual, introduced from Eurasia. First collected by H. Groh at Agassiz, BC, in 1931. Sporadic in gardens, roadsides, railway beds, and waste places in southern PQ, southern ON, and southern BC. Used extensively in experimental biology. 2n = 10, ON (Mulligan 1984).

Arabis caucasica Willd. Wall Rock-cress; — Corbeille d'argent

Self-incompatible, perennial, rock garden plant. Native of Eurasia. First collected by A. Hamel and A. Payette, in tidal debris, at Rivière-du-Loups, PQ, in 1949. Rare garden escape along a roadside in YT, and in cliff faces, tidal rocks, and tidal debris in NB, PQ, and ON. 2n = 16, ON (Mulligan 1964).

Arabis glabra (L.) Bernh. (= *Turritis glabra* L.) — Tower Mustard; Arabette glabre

Self-compatible, autogamous, biennial. Both native and introduced from Eurasia. First collected in a sandy field at London, ON, by T. W. Burgess, in 1879. Native on dry slopes in the Cypress Hills of SK and AB, and in the mountainous regions of southwestern AB and southern BC. Probably introduced into YT, NT-M, NB, PQ, ON, MB, SK, AB, and BC. Naturalized in sandy roadsides, waste places and field margins throughout its range. 2n = 12, PQ, ON, AB, and BC (Mulligan 1964; Taylor and Mulligan 1968; Mosquin in Mulligan 1995).

Arabis hirsuta (L.) Scop. var. *hirsuta* — Hairy Arabis; Arabette hirsute

Biennial or short-lived perennial, native of Europe. The only Canadian specimens were collected by E. Haber and M. J. Schepanek along a roadside in a campground in Glacier National Park, BC, on July 29, 1972, and by V. L. Harms, south of Swift Current Bay of Diefenbaker Lake, SK, on July 21, 1966. Probably introduced from populations known to occur in the United States.

Armoracia rusticana P. Gaertn., B. Mey. & Scherb. — Horseradish; Raifort

Self-incompatible perennial, introduced from Europe. Thick, deep, branching, woody roots used as source of sauce or relish. Naturalized in PQ as early as 1850 (Rousseau 1968). Roadsides, ditches, waste places, and old garden sites. Sporadic in PE, and from NB to BC. Once established, difficult to eradicate.

Barbarea stricta Andrz. — Small Flowered Winter Cress; Barbarée raide

Perennial, introduced from Europe. First collected at Gross-Ile, PQ, in St. Lawrence River, in 1944, by R. P. Hanson (Mulligan 1978). Jacques Cayouette has recently seen it at several locations on the island. He also collected it in Comté de Duplessis and Comté de Montmagny, in PQ, in 1979 (Cayouette 1984). It was reported to be at Temagami Forest Reserve, ON (Dorofeev 1998). May be more common than realized because of its confusion with the "typical phase" of *Barbarea vulgaris* and with *Barbarea orthoceras*.

Barbarea verna (Mill.) Aschers. — Early Winter Cress; Barbariée printanière

Biennial or short-lived perennial, introduced from Europe as a salad plant. First collected at St. Pierre, NF, by L. Arsène in 1900. Roadsides and waste places in NF and on Vancouver Island, BC.

Barbarea vulgaris (L.) W. T. Aiton — Yellow Rocket; Barbarée vulgaire

Self-incompatible perennial, introduced from Europe, probably as a common impurity in clover, alfalfa, and grass seed. Reproduces both by seed and cauline rosettes. First reported at Montreal in 1821 (Rousseau 1968). NF, PE, NS, NB, PQ, ON, MB, AB, and BC; mostly in non-cultivated fields, roadsides, and waste places. Sometimes used as salad or garnishing plant. See MacDonald and Cavers (1991). 2n = 16, ON (Mulligan 1959, 1984).

Berteroa incana (L.) DC. — Hoary Alyssum; Bertéroa blanc

Annual or winter annual, introduced from Europe. First collected at Wallbridge, ON, by Massey in 1893. Sporadic, but often locally abundant in NS, NB, PQ, ON, MB, SK, and BC. Non-cultivated fields, roadsides, waste places, and settlements; often on poorer soils. 2n = 16, ON (Mulligan 1957).

Brassica juncea (L.) Czern. — Indian Mustard; Moutarde d'Inde

Annual, introduced from Europe as a seed contaminant. Often cultivated for greens. Present in PQ in 1875 (Rousseau 1968) and was collected in a potato field, at Winnipeg, MB, by J. Fletcher in 1896. Cultivated fields, roadsides, and waste places in all provinces from NF to BC. Reaches greatest

abundance in Prairie Provinces. 2n = 36, AB (Mulligan 1959).

Brassica napus L. — Rape; Navet

Annual, introduced from Eurasia. Sporadic escape from cultivation. First collected at St. John, NB, by G. F. Matthew in 1874. Rare plant in cultivated and abandoned fields, roadsides, railways, and waste places in NT-M and every province from NF to BC.

Brassica nigra (L.) W. D. J. Koch — Black Mustard; Moutarde noire

Annual, introduced from Europe. An escape from cultivation and a seed contaminant. Naturalized in Canada since 1863 (Groh and Frankton 1946). Sporadic in cultivated fields, gardens, waste places, and roadsides in NF, NS, NB, PQ, ON, AB, and BC.

Brassica oleraceae L. — A great number of agricultural and horticultural varieties

Annual, introduced from Eurasia. Many cultivated varieties escape from cultivation but do not persist in Canada.

Brassica rapa L. (= *Brassica campestris* L.) — Bird Rape; Moutarde des oiseaux

Annual or winter annual, introduced from Eurasia. Has oil seed, vegetable, salad plant, and weed phases. Mostly introduced into fields as a contaminant in crop seed. In NS as early as 1829 (Rousseau 1968).Cultivated fields, roadsides, and waste places in YT, NT-M, and in all provinces from NF to BC. Most common in the Maritime Provinces, maritime areas of PQ, and the Fraser Valley and Vancouver Island of BC. 2n = 20, ON and BC (Mulligan 1959; Taylor and Mulligan 1968).

Bunias orientalis L. — Turkish Rocket; Bunias d'Orient

Perennial, introduced from Eurasia. Very sporadic in waste land and along roadsides in NS, NB, southern PQ, and southern BC. Does not persist except at a few locations on Vancouver Island and in the Fraser Valley of BC. Collected at Botanie, BC, by W. B. Anderson in 1927 and at the same site by F. Lomer in 1995.

Cakile edentula (Bigelow) Hook. var. *edentula* — Sea Rocket; Caquillier édentulé

Annual coastal strand herb, native to east coast but introduced on the west coast. In NF, PE, NS, NB, PQ, and BC. 2n = 18, PQ and BC (Mulligan 1964; Taylor and Mulligan 1968).

Cakile maritima Scop. — Sea Rocket; Caquillier maritime

Annual seashore strand herb, introduced from Europe. West coast, from Queen Charlotte Islands, BC, to Baja California. Sporadic along east and Gulf coasts of the United States (Rollins 1981).

Camelina alyssum (Mill.) Thell. (= *Camelina parodii* Ibarra & La Porte) — Flat-seeded False Flax; Caméline alysson

Annual, introduced from Europe as an impurity in crop seed. First collected at Middle Lake, SK, by W. W. Robins in 1910. Infrequent in cultivated fields, roadsides and waste places in the southern parts of MB, SK, and AB.

Camelina microcarpa Andrz. ex DC. — Small-seeded False Flax; Caméline à petits fruits

Self-compatible, autogamous, annual, introduced from Eurasia. Contaminant in flax and grain seed. First collected at Snelgrove, ON, by J. White in 1897. In all provinces, but most common in the Prairie Provinces. Open prairie, cultivated fields, roadsides, railway beds, and waste places. 2n = 40, AB and BC (Mulligan 1957, 1984).

Camelina sativa (L.) Crantz — Large-seeded False Flax; Caméline cultivée

Self-compatible, autogamous, annual, introduced from Eurasia. Contaminant in flax and grain seed. First collected at Fish Creek, AB, by J. Fowler in 1894. In YT (rare), NT-M, and from PQ to BC. Less common than small-seeded false flax. Prairies, cultivated fields, around grain elevators, roadsides, railways, and waste places. 2n = 40, AB and BC (R. J. Moore, unpublished).

Capsella bursa-pastoris (L.) Medik. — Shepherd's Purse; Bourse-à-pasteur

Autogamous, self-compatible, annual or winter annual, introduced from Europe. Recorded in New England as early as 1672 (Rousseau 1968) and in Nova Scotia as early as 1829 (Groh 1945). In YT, NT-M, N-F, and all provinces from NF to BC. Common plant in cultivated fields, pastures, meadows, roadsides, railway beds, and waste places, in all settled areas of Canada. 2n = 32, ON, SK and BC (Mulligan 1957, 1984; Taylor and Mulligan 1968).

Cardamine flexuosa With. — Wavy Bitter Cress; Cardamine flexueuse

Biennial or short-lived perennial, introduced from Europe. First collected in a park at St. John's, NF, by A. M. Ayre in 1927. Rare in wet springy banks and thickets in NF.

Cardamine hirsuta L. — Hoary Bitter Cress; Cardamine hirsute

Autogamous, self-compatible, annual, introduced from Europe. First collected at Vancouver, BC, by J. R. Anderson in 1896. Rare in ON, and common on Vancouver Island and in the Fraser Valley of BC. Old fields, gardens, ditches, roadsides, and waste places, usually in moist soil. 2n = 16, BC (Mulligan 1965).

Cardamine impatiens L. — Narrow Leaved Bitter Cress; Cardamine impatiente

Annual or biennial herb introduced from Europe. Only specimen seen was collected from a deciduous woods on St. Lawrence Starch Works property, Port Credit, ON, by J. M. Weber in 1980. It is sporadic and uncommon in the United States (Rollins 1981).

Cardamine pratensis L. — Cuckoo Flower; Cardamine des prés

Perennial. In YT, NT-M, N-K, N-F, NS, and from NB to BC. Plants in southern part of its range are mostly rare ornamental escapes of Eurasiatic origin. Plants in the northern part of its range, in Canada, are probably native.

Cardaria chalepensis (L.) Hand.-Mazz. — Lens-podded Hoary Cress; Cranson rampant

Strongly rhizomatous perennial, introduced into Canada and the United States in alfalfa seed imported from Turkestan about 1911 or 1912. First collected in the United States at Fargo, North Dakota, in 1912, and in Canada at Grande Prairie, AB, in 1926. In cultivated and non-cultivated habitats from ON to BC. Most abundant in irrigated areas of western Canada and the western United States. The three hoary cresses, found in Canada, now survive and spread primarily by extremely persistent vertical and horizontal roots. This is the most aggressive of the three hoary cresses. Fields, ditches, roadsides, pastures, and waste places; often on saline soils. See Mulligan and Findlay (1974). 2n = 80, SK, AB and BC (Mulligan and Frankton 1962).

Cardaria draba (L.) Desv. — Heart-podded Hoary Cress; Cranson dravier

Rhizomatous perennial, introduced from Europe and Western Asia. First collected in the United States at Long Island, New York, in 1862, and in Canada at Barrie, ON, in 1878. Present in NS, and from ON to BC. It is most troublesome in southern MB and southern AB. Cultivated fields, hayfields, pastures, irrigation ditches, roadsides, and waste places. Least weedy of the hoary cresses. See Mulligan and Findlay (1974). 2n = 64, AB (Mulligan and Frankton 1962).

Cardaria pubescens (C. A. Mey.) Jarmol. Globe-podded Hoary Cress; Cranson velu

Rhizomatous perennial introduced into Canada and the United States in alfalfa seed imported from Turkestan in 1911 or 1912. In MB, SK, AB, and BC. Often found in the same fields as lens-podded hoary cress, but not nearly as aggressive. First collected in the United States at Fargo, North Dakota, in 1912, and in Canada at Grande Prairie, AB, in 1926. In cultivated and non-cultivated fields, especially in irrigated areas where saline soils are present. See Mulligan and Findlay (1974). 2n = 16, SK and AB (Mulligan and Frankton 1962).

Chorispora tenella (Pallas) DC. — Blue Mustard; Chorispora fluet

Annual or winter annual, introduced from Asia. First collected at Penticton, BC, by J. W. Eastham in 1940. Very rare and often not persisting. In the southern parts of SK, AB, and BC. Very abundant in rangelands of the United States (Rollins 1981).

Conringia orientalis (L.) Dumort. — Hare's-ear Mustard; Vélar d'Orient

Autogamous annual or winter annual, introduced from Eurasia. First collected at Bass River, NB, by J. Fowler in 1872. In all provinces from NF to BC. Reaches greatest abundance in the Prairie Provinces, especially SK. Grain fields, disturbed prairie, pastures, roadsides, railways, and waste places.

Coronopus didymus (L.) Sm. — Lesser Swine Cress; Corne-de-cerf didyme

Annual or winter annual, introduced from Asia or South America. First collected on a wharf at Gaspé Basin, PQ, by J. Bell in 1862 and at North Sidney, NS, by T. W. Burgess in 1883. Rare in ballast, roadsides, waste places, and in old fields along the coasts of NF, NS, NB, PQ, and southern BC.

Coronopus squamatus (Forssk.) Asch. — Creeping Wart Cress; Corne-de-cerf écailleuse

Biennial or short-lived perennial, introduced from Europe. First collected on a wharf at Gaspé Basin, PQ, by J. Bell in 1862 and at St. John, NB, by J. Fowler in 1877. Rare in coastal areas of NS, NB, and PQ, and on lake shores in ON.

Descurainia sophia (L.) Webb. — Flixweed; Sagesse-des-chirurgiens

Autogamous, self-compatible, annual or winter annual, introduced from Eurasia. At Montreal, PQ, in 1821; probably reaching Canada with early French settlers (Rousseau 1968). First collected, in the prairies, at Plum Coulee, MB, by J. Fletcher in 1907, and at Antler, SK, by E. L. Stonehouse in the same year. In YT, NT-M, and from PE to BC. Most common in the Prairie Provinces, especially in cereal crops. Sporadic elsewhere. In disturbed grasslands, hay fields, grain fields, roadsides, and waste places. See Best (1977). 2n = 28, SK, AB and BC (Mulligan 1961b, 1984; Taylor and Mulligan 1968).

Diplotaxis erucoides (L.) DC. — White Rocket; Diplotaxe fausse-roquett

Annual or winter annual, native of Europe. In Canada, only known from PQ; Gaspé-Nord in 1904 and Laval in 1961 (Rousseau 1968). On ballast in New York City and in Camden, New Jersey, prior to 1880 (Rollins 1981). Very rare plant on ballast and in waste places. May not persist.

Diplotaxis muralis (L.) DC. — Sandrocket; Diplotaxe des murs

Autogamous, annual or winter annual, introduced from Europe. First collected on ship ballast at North Sydney, NS, and at Pictou, NS, by J. Macoun in 1883. Sporadic, but locally abundant, from PE to AB. In disturbed grassland, gardens, railway beds, and waste places, and around buildings.

Diplotaxis tenuifolia (L.) DC. — Wall-rocket; diplotaxe à feuilles ténues

Perennial, introduced from Europe. First collected at St. John, NB, by J. Fowler in 1877. NS, NB, PQ,

ON, and BC. Most common in southern ON; sporadic elsewhere. In waste places, ballast, railway beds, and along roadsides. 2n = 22, ON (Mulligan 1959).

Draba nemorosa L. Wood — Whitlow-grass; Drave des bois

Native, autogamous, annual or winter annual. In YT, NT-M, PQ, and from PQ to BC. Introduced in Eastern Canada and native elsewhere. Has colonized a wide variety of artificially disturbed habitats both within and outside of its native range. 2n = 16, ON, MB and AB (Mulligan 1966, 1975; Packer 1964; Löve and Löve 1982).

Draba verna L. — Whitlow-grass; Drave printanière

Autogamous, annual or winter annual, introduced from Europe. First collected at Quebec, PQ, by J. Bell in 1865. NB, and southern parts of PQ, ON, AB, and BC. In disturbed grasslands, railway beds, roadsides, and waste places, especially on light soils. 2n = 39, BC (Mulligan 1966).

Eruca vesicaria (L.) Cav. subsp. *sativa* (Mill.) Thell. — Garden-rocket; Roquette des jardins

Annual, introduced from Eurasia. Grown for salad purposes. First collected at Grenfell, SK, by Deacon in 1908. Early introductions were from contaminants in alfalfa seed (Groh 1944). Sporadic in waste places, cultivated fields, and roadsides in PQ, and southern parts of ON, SK, AB, and BC.

Erucastrum gallicum (Willd.) O. E. Schulz — Dog Mustard; Moutarde des chiens

Autogamous annual or winter annual, introduced from Eurasia. First collected at Emerson, MB, by H. Groh in 1943. Early collections were along railway beds, near grain elevators, and at grain shipping terminals. In cultivated fields, roadsides, railway beds, and waste places in NT-M, and from NF to BC. See Warwick and Wall (1998). 2n = 30, ON (Mulligan 1957, 1984).

Erysimum cheiri (L.) Crantz — Common Wallflower

Perennial, introduced from Europe, grown as an ornamental. An infrequent garden escape near Whitehorse, YT, at Ste-Foy, PQ, and on southeast Vancouver Island, B.C.

Erysimum cheiranthoides L. — Wormseed Mustard; Vélar fausse-giroflée

Autogamous annual or winter annual, introduced from Eurasia. First recorded in the United States, in Virginia, by Pursh in 1814 and, in Canada, by Hooker in 1830 (Rousseau 1968). Present in YT, NT-M, and in all provinces from NF to BC. In a wide range of disturbed habitats, but it is usually sparse at any single location. 2n = 16, ON and BC (Mulligan 1957, 1984; Taylor and Mulligan 1968).

Erysimum hieraciifolium L. Tall — Wormseed Mustard; Vélar à feuilles d'épervière

Apomictic biennial or short-lived perennial, introduced from Europe. First seen at Ottawa, ON, in 1941 and collected at Apple Hill, ON, by E. G. Anderson in 1946. In NS, NB, PQ, ON, and SK. Reaches greatest abundance, and is spreading rapidly, in roadsides, gravel pits, pastures, and hay fields in eastern ON. 2n = 48, meiosis irregular, ON (Mulligan and Frankton 1967).

Erysimum repandum L. — Treacle Mustard; Vélar étale

Annual or winter annual, introduced from Eurasia. First collected on Pelee Island, ON, by W. Botham in 1938. A rare mustard, present only at a few sites in waste places, railway beds, and roadsides in Essex and Kent Counties in southern ON, and in the Fraser Valley of BC.

Hesperis matronalis L. — Dame's Rocket; Julienne des dames

Perennial, introduced from Europe as an ornamental plant. Naturalized in PQ as early as 1862 (Rousseau 1968). Sporadic in old garden sites, roadsides, and waste places in all provinces. 2n = 24, ON (Mulligan 1984).

Hutchinsia procumbens (L.) Desv. (= *Horungia procumbens* (L.) Hayek) — Oval Shepherd's Purse; Hutchinsie couchée

Annual herb, introduced from Eurasia. First collected at Cache Creek, BC, by J. Macoun in 1875. Occurs at a few sites, on moist alkaline flats and seashores, in NF, MB, southern SK, and southern BC.

Iberis amara L. — Rocket Candytuff; Iberis amer

Annual, introduced from Europe as an ornamental. First collected at Lindsay, ON, in 1903 by W. Scott. A rare escape, in roadsides and waste places, in NS, and ON.

Iberis umbellata L. — Globe Candytuff; Iberis à ombelles

Annual, introduced from Europe as an ornamental. A rare escape from cultivation that is sometimes found in roadsides and waste places in PE, NS, and PQ.

Isatis tinctoria L. Dyers — Woad; Pastel des teinturiers

Biennial, formerly cultivated for its blue dye. Sparingly escaped from cultivation in NF, PQ, ON, and BC. First collected at Toronto, ON, by H. Groh in 1924. Only persists at a few locations in roadsides and waste places, in the Fraser Valley and on Vancouver Island of BC.

Lepidium species — Weedy Native Pepper-grasses; Lépidies

Four, autogamous, annual or biennial pepper-grasses are native in some parts of Canada, but have colonized a wide range of artificially disturbed habitats both within and outside of their native ranges.

Lepidium bourgeauanum Thell. — Bourgeau's Pepper-grass.

A biennial. In YT, NT-M, NF, NB, and PQ to BC. Native to Prairie Provinces but introduced elsewhere. 2n = 32, ON and BC (Mulligan 1961a).

Lepidium densiflorum Schrad. — Common Pepper-grass; Lépidie densiflore.

An annual. In YT, NT-M, and from NF to BC. Native to Prairie Provinces and interior of BC and introduced elsewhere. 2n = 32, ON, SK and BC (Mulligan 1961a,b and 1984).

Lepidium ramosissimum A.Nelson — Western Pepper-grass.

A biennial. In NT-M, ON, MB, SK, AB, and BC. Native of Prairie Provinces and introduced elsewhere. 2n = 64, NT-M, SK and AB (Mulligan 1961a).

Lepidium virginicum L. — Poor-man's Pepper-grass; Lépidie de Virginie.

An annual. In NF, PE, NS, PQ, ON and southwestern BC. Native to Fraser Valley and adjacent Vancouver Island in BC, but introduced in the east from further south in the United States. 2n = 32, ON and BC (Mulligan 1961a).

Lepidium aucheri Boiss.

Introduced from Europe. Only specimen seen was collected on Bull grounds, Toronto, ON, by W. Scott on August 20, 1904.

Lepidium campestre (L.) R.Br. — Field Pepper-grass; Lépidie des champs

Autogamous annual or winter annual, introduced from Europe. First collected at Hamilton, ON, by J. M. Buchan in 1870 (Rousseau 1968). In all provinces of Canada; cultivated fields, roadsides, waste places, and railroad beds. Most common and abundant in the southern parts of PQ, ON, and BC; sporadic elsewhere. 2n = 16, ON, SK and BC (Mulligan 1957; Taylor and Mulligan 1968).

Lepidium heterophylum (DC.) Benth. — Smith's Pepper-grass; Lépidie à feuilles dissemblables

Perennial, introduced from Europe. Well established along roadsides and in waste places on Vancouver Island, B.C. First collected at Courtenay, BC, by W. E. Molyneux in 1955.

Lepidium latifolium L. — Perennial Pepper-grass; Lépidie à feuilles larges

Perennial, with subterranean rhizomes, introduced from Europe. Only known in Canada at Quebec, PQ, near Lethbridge, AB, and at Wycliffe, in the East Kootenay region of BC. It has persisted and spread locally at all three locations. It was first collected, in the railroad shop yard at Quebec, PQ, by Br. Marie-Anselm in 1931 and was discovered, in irrigated land, near Lethbridge, AB, by K. W. Hill in 1940. 2n = 24, AB (Mulligan 1957).

Lepidium oxycarpum Torr. & A. Gray. — Forked Pepper-grass

Annual, introduced from the United States. Only Canadian specimen seen was collected at Cadboro Bay, Vancouver Island, BC, by J. Macoun in 1893.

Lepidium perfoliatum L. — Clasping-Leaved Pepper-grass; Lépidie perfoliée

Autogamous annual, introduced from Europe. Often breaking off at base to act as a tumbleweed for seed dispersal. First collected at Osoyoos and Cranbrook, BC, by H. Groh in 1931. In southwest PQ, and in the southern parts of ON, MB, SK, AB, and BC. Most common in cultivated fields, overgrazed rangeland, roadsides, and waste places in the drier regions of the Prairie Provinces and inland valleys of BC.

Lepidium ruderale L. — Roadside Pepper-grass; Passerage des decombres

Autogamous annual or winter annual, introduced from Eurasia. First collected by J. Fowler at Bass River, NB, in 1868. Sporadic in roadsides, waste places and settlements from NF to SK.

Lepidium sativum L. — Garden Cress; Lépidie cultivée

Annual, introduced from Europe as a salad green. First collected at Ottawa, ON, by W. Scott in 1890. Sparingly escaped to roadsides, waste places and settlements in YT, NT-M, and from PE to BC.

Lobularia maritima (L.) Desv. — Sweet Alyssum; Allysson maritime

Perennial ornamental, native to the Mediterranean region, that normally acts as an annual under our conditions. First collected at Tring Junction, PQ, by H. Groh in 1927. Has been collected in NS, southern PQ and ON, and on Vancouver Island BC. It does not appear to persist except on Vancouver Island.

Lunaria annua L. — Honesty; Monnaie-du-pape

Annual or biennial, native of Europe, grown for ornamental purposes. First collected at Revelstoke, BC, by H. Groh in 1939. Has been collected in old garden sites, roadsides, and waste places in NS, PQ, ON, MB, and BC. Does not persist.

Malcolmia maritima (L.) W. T. Aiton — Virginia Stock; Malcolmie maritime

Annual ornamental, introduced from Europe. First collected as a garden escape, at Durham, ON, by W. Scott, in 1897. It has not been collected since that time.

Matthiola longipetala (Vent.) DC. (= *Matthiola bicornis* (Sm.) DC.) — Evening Stock

Annual or winter annual ornamental, native of Eurasia. First collected at Saskatoon, SK, by H. Groh in 1935. Collected, at a few sites, in settlements and roadsides, in ON, SK, and AB. Does not persist.

Myagrum perfoliatum L. — Mitre Cress; *Myagrum perfolie*

Annual, native of Eurasia. Sometimes grown as an ornamental. Collected at Gallow's Hill, PQ, by Brodie in 1895. The only other record is based on a specimen collected in the 1940s at Rigaud, PQ (Groh and Frankton 1946). There is no evidence that it can persist in nature.

Nasturtium crystallinum (Rollins) G. A. Mulligan — Asiatic Cress

Perennial with a very thick root. Probably introduced from Asia and utilized to produce a condiment. First collected by Thieret and Reich at mile 39, Yellowknife Highway, 26 miles northeast of Fort Providence, NT-M, in 1961. This is the only known location for this mustard in North America. Another specimen was collected, from the large patch growing at this site, by W. J. Cody in 1965. This is a location that was formerly farmed by a religious community. 2n = 32, NT-M (Mulligan and Cody 1995).

Nasturtium microphyllum Boenn. ex Rchb. — Northern Water-cress; Cresson de fontaine

Perennial, aquatic to semi-aquatic, rooting at nodes. Introduced from Europe as a salad plant and has spread from deliberate plantings into cold streams. First collected in Canada at London, ON, by T. W. Burgess in 1879. Collected intermittently in cool water habitats in NF, PE, NB, PQ, ON, MB, and BC. Most common in southern ON. 2n = 64, PE and ON (Mulligan 1984).

Nasturtium officinale W.T. Aiton — Southern Water-cress; Cresson de fontaine

Perennial, aquatic to semi-aquatic, rooting at nodes. Introduced from Europe as a salad plant and has spread from deliberate plantings in cold streams. First collected in Canada at London, ON, by T. W. Burgess in 1878. Intermittently established in cool water in NF, NS, NB, PQ, ON, MB, AB, and BC. Most common in southwestern BC. Frequently confused with northern water-cress. *Nasturtium officinale,* a diploid (2 n = 32), is the most common water-cress in the United States, whereas *Nasturtium microphyllum,* a tetraploid (2 n = 64), is most common in Canada (Green 1962).

Neslia paniculata (L.) Desv. — Ball Mustard; Neslie paniculée

Self-compatible, autogamous, annual or winter annual, introduced from Europe. Pods, that do not open when ripe, are frequently an impurity in grain seed. First collected on a railroad embankment at Silver City, AB, by J. Macoun in 1885. In YT, NT-M, and all provinces from NF to BC. Common in grain and other cultivated fields in Western Canada, particularly in the Peace River Districts of AB and BC. Sporadic elsewhere in roadsides, railway embankments, waste places, and near grain elevators. 2n = 14, ON and BC (Mulligan 1957; Taylor and Mulligan 1968).

Raphanus raphanistrum L. — Wild Radish; Radis sauvage

Annual or winter annual, introduced from Europe. Present in Nova Scotia as early as 1829 (Rousseau 1968). In all provinces from NF to BC. Very abundant in cultivated fields along the Atlantic seaboard and in the Fraser Valley and Vancouver Island of BC. Sporadically distributed elsewhere, mostly due to contaminants in grain shipments. 2n = 18, NB (Mulligan 1961b).

Raphanus sativus L. — Radish; Radis

Annual, native of Mediterranean region, that is a sporadic escape from cultivation. Collected in NS, NB, PQ, ON, MB, SK, and BC, but does not persist, except in the Fraser Valley and Vancouver Island of BC. Sometimes hybridizes with wild radish in the Fraser Valley.

Rapistrum perenne (L.) All. — Steppe Cabbage; Rapistre vivace

Deep rooted perennial, introduced from Europe. First collected, at its only known location, at Grenfell, SK, in 1928 (Groh 1944). It has persisted and spread locally in roadsides, waste places, and cultivated fields.

Rapistrum rugosum (L.) All. — Turnip Weed; Rapistre rugueux

Annual, introduced from Europe. First collected at Montreal, PQ, by J. M. Wallace in 1893. Collected at a few widely separated sites, in waysides, and waste places in PQ and ON. Does not seem to persist.

Rorippa amphibia (L.) Besser — Amphibious Water Cress; Cresson amphibie

Aquatic to semi-aquatic perennial, introduced from Europe. Rhizomes are believed to have been introduced at the port of Montreal, PQ, in ballast from early European ships. It occurs along the St. Lawrence River from Montreal to Quebec, PQ, and along the Richelieu River at St-Ours, PQ (see Rousseau 1968).

Rorippa austriaca (Crantz) Besser — Austrian Yellow Cress; Cresson d'Autriche

Rhizomatous perennial, introduced from Europe. First collected at Greenstreet, SK, by Patmore in 1932. In a few widely scattered localities in MB, SK, and AB. Is in pastures, cropland, and waste places, usually where moisture is plentiful.

Rorippa calycina (Engelm.) Rydb.

Rhizomatous perennial, probably introduced into Canada, from its native range further south in the United States, by migrating waterfowl. Only known in Canada from the mouth of the Anderson River, NT-M (Mulligan and Porsild 1966). First collected by T. W. Barry in 1962, and in the same area by G. W. Scotter in 1965.

Rorippa sylvestris (L.) Besser — Creeping Yellow Cress; Rorippa sylvestre

Rhizomatous perennial, introduced from Europe. Self-incompatible, rarely setting seed pods in nature. Spread mainly by root fragments. First collected at Ball's Mills, Lincoln County, ON, by McCalla in 1897. In all provinces from NF to BC. Present in gardens, ditches, disturbed stream banks, moist meadows, plant nurseries, and waste places. 2n = 32, PQ and ON; 2n = 40, ON and BC; 2n = 48, NB, PQ, ON, AB and BC (Mulligan and Munro 1984).

Sinapis alba L. — White Mustard; Moutarde blanche

Annual, native of Mediterranean region. Cultivated for the manufacture of mustard from seeds, and to a lesser extent for greens. Growing wild in Canada as early as 1860 (Groh and Frankton 1946). Sporadic in fields, disturbed prairie, roadsides, railway beds, and waste places, in PE and from PQ to BC. Often does not persist.

Sinapis arvensis L. — Wild Mustard; Moutarde des champs

Self-incompatible annual, introduced from the Mediterranean region. Common in fields of Albany, New York, as early as 1748, in NS in 1829 and by 1840 had reached the western and northern part of the state of New York and Lower Canada. In Fort Garry, MB, in 1860 and is now through all settled areas of Canada (Mulligan and Bailey 1975). Now in YT, NT-M, and all provinces. Jacobson et al. (1988) presented some evidence that charred seeds uncovered at excavations of abandoned native sites in the northeastern United States and dated at 8000 B.P. (before present), were wild mustard seeds. Rollins (1993) found their evidence unconvincing, and I agree with him. Very common in grain fields, other cultivated fields, and waysides in the Canadian prairie region, but less common elsewhere. It is a common contaminant in grain seed. Poisoning and death have occurred when large quantities of screenings were fed to animals (Mulligan and Munro 1990). See Warwick et al. (2000). 2n = 18, ON, MB, SK, AB and BC (Taylor and Mulligan 1968; Mulligan 1984; Warwick et al. 1994).

Sisymbrium altissimum L. — Tumble Mustard; Sisymbre élevé

Autogamous annual or winter annual, introduced from Eurasia. First collected at Silver City, AB, by J. Macoun in 1885. Often breaking off at the base, acting as a tumbleweed for seed dispersal. In YT, NT-M, and in all provinces from NF to BC. Most abundant in grain fields and grasslands of the prairies of Western Canada. Mostly in roadsides, railway beds, and waste places elsewhere in Canada. 2n = 14, ON, SK and BC (Mulligan 1961b, 1984; Taylor and Mulligan 1968).

Sisymbrium loesellii L. — Tall Hedge Mustard; Sisymbre de Loesel

Autogamous annual or winter annual, introduced from Europe. First collected by N. Criddle in SK in 1929. Occurs from NB to BC. Most common in grain fields and other cultivated fields in the Prairie Provinces; sporadic in roadsides and waste places elsewhere. 2n = 14, AB (Mulligan 1957).

Sisymbrium officinale (L.) Scop. — Hedge Mustard; Sisymbre officinal

Annual, introduced from Europe. Seen at Prescott, ON, by B. Billings in 1862 (Rousseau 1968). Occurs in all provinces, except SK. Primarily a garden and waste place weed. It is often found near farm buildings. 2n = 14, BC (Taylor and Mulligan 1968).

Sisymbrium orientale L. — Eastern Tumble Mustard

Annual herb, introduced from Eurasia. Rare in mesic to dry fields, roadsides, and waste places at Vancouver, BC (Douglas et al. 1998).

Teesdalia nudicaulis (L.) R.Br. — Shepherd's Cress; Teesdalie à tige nue

Annual or winter annual, introduced from Europe. Sporadically naturalized in disturbed habitats on southern Vancouver Island and in the Fraser Valley of BC. First collected in Locarno Park, Vancouver, BC, by J. Eastham in 1938, and it continues to persist at that site.

Thlaspi arvense L. — Stinkweed; Tabouret des champs

Autogamous annual or winter annual, introduced from Europe. It was a common weed around Detroit as early as 1818 and, in Canada, at Fort Garry, MB, in 1865 (Best and McIntyre 1975). In YT, NT-M, and all provinces from NF to BC. In grain fields, hay fields, gardens, roadsides, and railway beds. When grazed, produces an off-flavor in dairy products (Frankton and Mulligan 1987). 2n = 14, ON, SK, and AB (Mulligan 1957, 1984; Pringle 1969).

Acknowledgments

The publications, *Weeds of the Cruciferae (Brassicaceae) in North America* (Rollins 1981) and *Histoire, habitat et distribution de 220 plantes introduites au Québec* (Rousseau 1968) have been especially useful to me. The common names are mostly from *Common and scientific names of weeds in Canada/Noms populaires et scientifiques des plantes nuisible du Canada* (Darbyshire et al. 2000). I am also indebted to the many people who documented the first sightings and later spread of our introduced mustards in their publications or by depositing specimens in various herbaria.

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Additional Records of Bigeye Fishes (Priacanthidae) from the Atlantic Coast of Nova Scotia, Including the First Record of the Glasseye Snapper, *Heteropriacanthus cruentatus*

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Three species of the bigeye fish family, Priacanthidae, are recorded from Nova Scotia based on new material. The specimens are all juveniles, one of the Glasseye Snapper, *Heteropriacanthus cruentatus*, eight of the Bigeye, *Priacanthus arenatus*, and two of the Short Bigeye, *Pristigenys alta*. The record of the Glasseye Snapper is the first for Canada and a northward range extension of over 1000 km for the species. A key to the four species of western Atlantic bigeyes is given.

Key Words: Glasseye Snapper, *Heteropriacanthus cruentatus*, first record, Nova Scotia, Canada, Bigeye, *Priacanthus arenatus*, Short Bigeye, *Pristigenys alta*, Priacanthidae

The bigeyes (Priacanthidae) are a small family of carnivorous fishes, feeding on coral reef fishes, crustaceans and worms. As their name indicates they have large eyes. The mouth is also large and very oblique with the lower jaw projecting. The scales are small and strongly ctenoid making bigeyes rough to the touch. Scales cover the body, head, the maxilla bone of the upper jaw and the lower jaw. The dorsal fin usually has 10 spines followed by 10–15 soft rays without a strong notch between spines and soft rays. The anal fin has 3 spines and 9 to 16 soft rays. The pelvic fin has one spine and five soft rays and is connected to the body by a membrane. There are 14 branched caudal fin rays. Bigeyes are usually bright red in colour (Coad et al. 1995). Bigeye fishes are usually nocturnal and are common on coral reefs and around rocky areas where they hide in crevices during the day. Adults may be found deeper than 400 metres. Young bigeyes are associated with floating debris near the surface in open ocean and are widely dispersed by ocean currents (Coad et al. 1995). Their occurrence along the coast of Nova Scotia is attributed to transportation within eddies of Gulf Stream surface water. Like a number of juvenile tropical fishes known to occur during the summer months along the coast of Nova Scotia, they survive until autumn and die when water temperatures drop.

The bigeye family of fishes is primarily circumtropical in distribution. There are about 18 species known from the Atlantic, Indian and Pacific oceans. Only four species occur in the western Atlantic: Bulleye, *Cookeolus japonicus* (Cuvier, 1829), Bigeye, *Priacanthus arenatus* Cuvier, 1829, Short Bigeye, *Pristigenys alta* (Gill, 1862) and Glasseye Snapper, *Heteropriacanthus cruentatus* (Lacepède, 1801). The first three species were reported from Nova Scotia by Scott and Scott (1988) and Coad et al. (1995). The latter species is reported for the first time from the Canadian Atlantic.

Bigeye fishes are rarely recorded from the Atlantic coast of Nova Scotia. MacKay and Gilhen (1973) first recorded the capture of a 147.0 mm total length Bulleye [*Cookeolus boops* (Forster in Bloch and Schneider, 1801) = *Cookeolus japonicus* (Cuvier, 1829)] from Indian Point, St. Margarets Bay, Halifax County, on 16 September 1971 and a 41.7 mm approximate standard length Bigeye removed from the pharynx of a Pollock, *Pollachius virens* Linnaeus, 1758, caught on a hook and line at Gulch Shoal, off Hopson Island, Halifax County, on 8 September 1972. Scott and Scott (1988) included these and recorded a third species, a 22 mm total length Short Bigeye from near Corsair Canyon at 42°33′N, 64°35′W.

In this paper, we record eight more specimens of Bigeye, two more specimens of Short Bigeye, and the first Canadian record of the Glasseye Snapper, all from the coastal waters of Nova Scotia in the 1990s. The record of the Glasseye Snapper confirms the presence of all four western Atlantic bigeye species in Canada.

Catalogue Data

Glasseye Snapper, *Heteropriacanthus cruentatus* (Figure 1)
NSM (Nova Scotia Museum) *10037*, 63.0 mm SL (standard length), from a mackerel trap, Red Bank, St. Margarets Bay, Halifax County, 44°37′32″N, 64°01′55″W, 18 October 1990, Eric Newton and Brian Coolen. This specimen is the first Canadian record.

FIGURE 1. A juvenile (63.0 mm SL) Glasseye Snapper, *Heteropriacanthus cruentatus*, first record for the Canadian Atlantic, captured in a mackerel trap at Red Bank, St. Margarets Bay, Halifax County, Nova Scotia on 18 October 1990 by Eric Newton and Brian Coolen (NSM10037; negative N-24, 439).

Bigeye, *Priacanthus arenatus* (Figure 2)
NSM 10092, 70.6 mm SL, caught alive in a mackerel trap set off Red Bank, St. Margarets Bay, Halifax County, 44°37′32″N, 64°01′55″W, 17 September 1990, Eric Newton and Brian Coolen. This specimen is the second record for Nova Scotia.
NSM 85350, 45.7 mm SL, found freshly dead at the strand line on the day after Hurricane Edward on Hirtle Beach, Lunenburg County, 44°27′05″N, 64°21′18″W, 3 September 1996, J. Sherman Bleakney.
NSM 11796, 52.8 mm SL, *NSM 11797*, 50.2 mm SL and *NSM 11798*, 55.7 mm SL, caught alive mixed in with a large school of Butterfish, *Peprilus triacanthus* Peck, 1804, in a mackerel trap set off Joe Shatford's Lobster Pound, Fox Point, St. Margarets Bay, Lunenburg County, 44°37′01″N, 64°03′00″W, 10 October 1996, Eric Newton and Brian Coolen.

NSM 85345, *NSM 85346* and *NSM 85347*, 43.9–64.4 mm SL, washed up at high water mark, presumed to have been killed by a drop in sea temperature from 20°C to 14°C owing to a coastal upwelling occasioned by southwesterly winds, Clam Harbour Beach, Halifax County, 44°43′30″N, 62°53′25″W, 10 September 1999, Patrick Ryall.

Short Bigeye, *Pristigenys alta* (Figure 3)
NSM 10033, 19.4 mm SL, found freshly dead on sandy shore, Sambro Creek area, Indian Harbour, Halifax County, 44°28′17″N, 63°37′00″W, 29 August 1990, Daniel Peters. This specimen is the second record for Nova Scotia
NSM 10035, 25.3 mm SL, scooped up alive in a bucket of seawater, off Hopson Island, vicinity of Prospect, Halifax County, 44°27′00″N, 63°47′30″W, 31 August 1990, Ron Duggan.

Descriptions of the Canadian Specimens

Detailed accounts of the anatomy, colour and distribution of these species may be found in Caldwell (1962) and Starnes (1988). All specimens are juveniles and differ in colour from adults.

Heteropriacanthus cruentatus

The single specimen has a dorsal fin with rays X, 13 (10 spines and 13 soft rays), an anal fin with rays III, 14, a pectoral fin with 18 rays, 85 lateral series scales, 11 scales between the dorsal origin and the lateral line, and 23 total gill rakers. Head length (HL) in standard length (SL) is 2.8, head width in

FIGURE 2. A juvenile (70.6 mm SL) Bigeye, *Priacanthus arenatus*, second record for the Canadian Atlantic, captured in a mackerel trap at Red Bank, St. Margarets Bay, Halifax County, Nova Scotia on 17 September 1990 by Eric Newton and Brian Coolen (*NSM 10092;* negative N-24, 438)

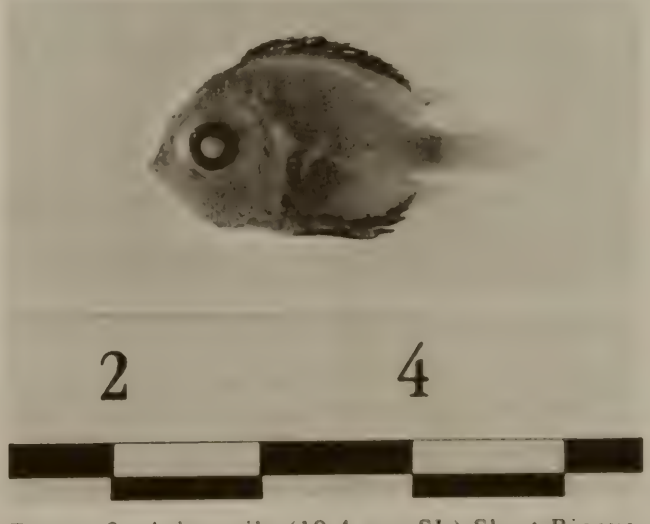

FIGURE 3. A juvenile (19.4 mm SL) Short Bigeye, *Pristigenys alta*, second record for the Canadian Atlantic, found freshly dead on sandy shore, Sambro Creek, Halifax County, 29 August 1990 by Daniel Peters (*NSM 10033*; negative N-25, 618).

HL is 1.9 (in SL 5.3), body width in SL is 5.6, head depth in SL is 2.5, body depth at the sixth dorsal fin spine level is 2.2 in SL, snout length in HL is 3.7 (10.3 in SL), orbital diameter in HL is 2.1 (6.0 in SL), interorbital distance in HL is 3.0 (8.3 in SL), length of the lower jaw in HL is 1.7 (4.7 in SL), pectoral fin length in HL is 1.9 (5.3 in SL), pelvic fin length in HL is 1.5 (4.2 in SL), caudal peduncle length in SL is 6.9, caudal peduncle depth in SL 10.3, longest dorsal fin spine in SL is 6.1, longest dorsal fin soft ray in SL is 6.6, and longest anal fin soft ray in SL is 6.7.

This specimen lacks scales on the chin and on the preopercle bone posterior to the shelf overlying the sensory canal, in contrast to the superficially similar *Priacanthus arenatus*. When freshly frozen it was a bright blue over the back and upper sides down to below the lateral line. The sides, from the back of the head to the base of the caudal fin, had six dark, uneven bands, interspersed with subtly paler elongate blotches which extend from the back to below the lateral line. The lower sides and belly were silvery-white with a distinct pinkish-red sheen. There were three small, dark-blue blotches on the lower sides above the anal fin. The eyes were a glossy orange-red. Fins were greyish at the base, with orange-brown spots, becoming blue-black along the outer edge, most prominently at the posterior edge of the caudal fin. In the preserved fish, the caudal fin shows rows of spots not seen in the *Priacanthus arenatus* juveniles. The dorsal and anal fins have a similar pigmentation to *P. arenatus*.

The northernmost record of this species was a single record of a juvenile from off Cape May, New Jersey, itself a northward range extension from Southern Florida (Caldwell 1962; Starnes 1988). The Canadian record is a range extension of over 1000 km.

Priacanthus arenatus

The eight specimens have a dorsal fin with rays X, 14 (6 fish) or X, 15 (2), an anal fin with rays III, 15 (6) or III, 16 (2) and a pectoral fin with 17 (3)or 18 (4) rays (one damaged). Total gill rakers are 29 (4) or 30 (4). Head length in SL is 2.8–2.9 (mean 2.9), pelvic fin length in HL is 1.1–1.4 (mean 1.2), and body depth at the sixth dorsal spine level is 2.4–2.7 (mean 2.5) in SL.

NSM 10092 was a bright orange with a pinkish-purple sheen. The body and fins were peppered with small black dots which are probably due to a parasite. Pelvic fins were bordered in black and the pupil of the eye was deep blue. *NSM 85350* was a pale pink with rosy bars. Preserved fish have the membranes of the spiny dorsal and anal fins darkly pigmented while the anterior and basal parts of the soft dorsal and anal fins are less darkly pigmented. The pelvic soft rays and membranes are very darkly pigmented while the spine is contrastingly clear. The body is brownish dorsally, silvery on the sides from scale reflections and silvery to whitish on the belly. The caudal fin may have a posterior margin band, particularly evident centrally.

Pristigenys alta

The two specimens have a dorsal fin with rays X, 11 (2), an anal fin with rays III, 10 (2), and a pectoral fin with 17 (1) or 18 (1) rays. Total gill rakers are 26 (2). Head length in SL is 2.8–2.9 (mean 2.9), pelvic fin length in HL is 1.1–1.2 (mean 1.2), and body depth at the fourth dorsal fin spine level is 1.7 in SL.

There are no colour notes on fresh specimens of this species but the preserved material has a spiny dorsal fin with three bands which are partly reticulate. The soft dorsal fin is darkened at its base. The anal fin spines and membranes are dark and the soft rays are dark basally. The pelvic fin spine has four bars and the soft rays and membranes are dark.

The low counts of dorsal and anal soft fin rays and of lateral series scales are distinctive for this genus and species of bigeye.

Key to the bigeyes (Priacanthidae) found in the Canadian Atlantic.

1A. Anal fin soft rays 9–11, usually 10; dorsal fin soft rays 10–12, usually 11; scales in lateral line series 45 or less — *Pristigenys alta*

1B. Anal fin soft rays 12–16; dorsal fin soft rays 12–15, usually 13–14; scales in lateral line series 58 or more — 2

2A. Pelvic fin length much greater than head length; scale rows between dorsal fin origin and lateral line 16–20; preorbital bone with strong anterior serrations — *Cookeolus japonicus*

2B. Pelvic fin length usually shorter than head length in young to slightly longer; scale rows between dorsal fin origin and lateral line less than 16; preorbital bone with fine anterior serrations — 3

3.A. Chin tip and posterior preopercle bone lacking scales; total gill rakers 21–25; anal fin soft rays 13–14, usually 14; dorsal fin soft rays 12–13, usually 13 — *Heteropriacanthus cruentatus*

3B. Chin tip and posterior preopercle bone scaled; total gill rakers 27-33; anal fin soft rays 14–16, usually 15; dorsal fin soft rays 13–15, usually 14 — *Priacanthus arenatus*

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An Extraordinary Raccoon, *Procyon lotor,* Density at an Urban Park

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We report on a high density Raccoon (*Procyon lotor*) population at a 70.9 ha urban park in Fort Lauderdale, Florida, where in a 5-day period 160 raccoons were removed and 9 others observed without capture. This represents a minimum density of 238 raccoons/km^2, and is one of the densest Raccoon populations reported. We discuss the ramifications of high density urban Raccoon populations relative to wildlife disease contagions and endangered species protection.

Key Words: Raccoon *Procyon lotor*, endangered species protection, Florida, Fort Lauderdale, rabies, wildlife diseases.

Hugh Taylor Birch State Park (HTBSP) is in Broward County, Florida, USA, within the limits of the City of Fort Lauderdale. It was initially obtained as public lands by the State of Florida on 31 December 1941. It consists of 56.7 ha of upland vegetation, and 14.2 ha of freshwater and tidal wetlands, for a combined total of 70.9 ha. Terrestrial plant communities consist of disturbed maritime hammock and patchy areas dominated by exotic Australian Pine (*Casuarina equisetifolia*). HTBSP is completely contained within Fort Lauderdale which had a 1990 population census of ca. 150 150 (Fort Lauderdale Community and Economic Development Department), and is surrounded by urban infrastructure to the north and south. The property is bordered to the east by additional infrastructure and the Atlantic Ocean; the Intracoastal Waterway (a large bulkheaded canal) truncates the entire western boundary.

Raccoon (*Procyon lotor*) population densities in HTBSP have always been high since the first Southeast Florida district park biologist was hired in 1970 (R. Roberts, personal communication); however, densities were not quantified. During the 1980s, tourists and local residents began the evening practice of feeding Raccoons immediately outside the south boundary of the park, principally at the park drive entrance gate area along the Sunrise Boulevard right-of-way and the contiguous City Fire Station entrance. Although feeding of wildlife is unlawful inside all state parks, until November 2000 it was unregulated outside of HTBSP, including at the entrance. Efforts to control this practice included public environmental education about the detriments of feeding wildlife resources. Coarse, irregular estimates of the Raccoon population at the Park during the late 1990s ranged from 75 to 125 animals (H. Smith, personal observation).

The high density Raccoon population presented a threat of epizootic disease transmission and bites to humans. High concentrations in urban areas and a willingness to accept food from humans by an animal that many members of the public view as endearing create a much higher probability for human-animal contact than with many other wildlife species. The animals also presented constant vehicular traffic problems in the evenings. A control program was conducted in November 2000 to reduce these hazards by reducing the abundance of Raccoons. Public sentiment restricted the approach to a "one-time only" live-trap and relocate program. This was cooperatively arranged between the Florida Department of Environmental Protection, Florida Fish and Wildlife Conservation Commission, and the City of Fort Lauderdale. Raccoons were captured using 80 × 25 × 30 cm Tomahawk live traps (P.O. Box 323, Tomahawk, Wisconsin 54487; use of product names does not constitute endorsement by the U.S. government, nor the Florida state government), baited with cat food.

On the evening of 14 November, 123 Raccoons were captured and relocated by permit to a site south of Homestead, over 88 km away. On the evening of 15 November, HTBSP was again surveyed with 36 Raccoons observed. On the evening of 17 November, 37 additional Raccoons were trapped and relocated to the same site. On the evening of 18 November, active enforcement was initiated of City of Fort Lauderdale Ordinance No. C-00-48, Sec. 6-15 "Feeding of Wild Animals Prohibited." A final survey that evening produced a count of nine raccoons near the park drive entrance gate. Thus, an absolute minimum number of Raccoons inhabiting the park area prior to removal efforts was 169. It is virtually impossible that any of the relocated Raccoons could have returned to be trapped more than once because of the great distance to the relocation site, the habitat, including waterways and bridges they would have to cross through urban Fort

Lauderdale, and the short (5 day) time frame in which all work was completed. Thus, the minimal Raccoon density for HTBSP at the time this work was implemented was 238/km^2.

Artificially enhanced populations of Raccoons are a problem in wildlands and urban-suburban areas of Florida (Heugel 1991*), and on a more cosmopolitan level (e.g., Rosatte et al. 1992a). Due to the high degree of habitat alteration, fewer species inhabit urban environments than natural environments. However, for those species that inhabit urban environments, increased availability and concentration of food, den sites or other refuges may induce dense populations (e.g., Dickman 1987; Dickman and Doncaster 1987; Riley et al. 1998).

The highest Raccoon density we could find in the literature came from one small (30 ha) section in Rock Creek Park (710 ha total) in Washington, D.C., where the density was estimated as high as 333/km^2, and estimated Raccoon densities from other study sites in the same park ranged as high as 172/km^2 (Riley et al. 1998). Estimated densities of raccoons in metropolitan Toronto, Ontario, ranged as high as 140/km^2 (Rosatte et al. 1992a). The minimal potential density we observed for HTBSP ranks as one of the densest congregations of Raccoons recorded (see Riley et al. 1998 for a range of Raccoon densities). Its Raccoon density was over 4 to 200 times as great as reported rural Raccoon densities (0.9-55.6/km^2) (Mech et al. 1968; Johnson 1970; Urban 1970; VanDruff 1971; Sonenshine and Winslow 1972; Lehman 1977*; Keeler 1978; Lehman 1980*; Orloff 1980*; Slate 1980*; Rabinowitz 1981; Jacobson 1982; Nottingham et al. 1982; Lehman 1984*; Moore and Kennedy 1985; Leberg and Kennedy 1988; Perry et al. 1989; Hasbrouck 1991; Kennedy et al. 1991; Hable et al. 1992; Nixon et al. 1993*). The high rural density of 250/km^2 reported by Twichell and Dill (1949) may be an anomaly for rural populations as it too was 4-200 times greater than the other reported rural densities at 0.9-55.6/km^2. Rosatte et al. (1992b) and Rosatte (2000) demonstrated the patchiness of Raccoon densities in urban habitats when large areas are trapped. Many of the high densities reported, including our observations, involved small urban parks presenting large numbers of Raccoons. Densities outside HTBSP were probably much lower.

High densities of Raccoons at HTBSP posed a concern for various reasons. First, a number of diseases are endemic in raccoon populations, in particular, rabies (Winkler and Jenkins 1991). Raccoons are the most common vectors of rabies in the U.S. (Krebs et al. 2001), and two-thirds of all rabid animals in Florida have been Raccoons (Burridge et al. 1986). A large number of uncommonly reported species have been found rabid in association with Raccoon rabies epizootics (Burridge et al. 1986), in part due to Raccoon usage of urban resources (Winkler and Jenkins 1991). Urban Raccoons are of particular concern for wildlife disease control (e.g., Broadfoot et al. 2001). Most human exposures have been largely due to failure to apply common sense in interacting with Raccoons (Jenkins and Winkler 1987; Jenkins et al. 1988). It follows that a high-density Raccoon population in an urban setting, especially where people have become enamored of them or accustomed to feeding them, as at HTBSP, presents a high-risk recipe for human exposure to rabies during an outbreak (e.g., Kappus et al. 1970; Jenkins and Winkler 1987; Jenkins et al. 1988). We would not expect future high-density urban Raccoon situations in Florida to be addressed with a trap and relocate program due to legal and wildlife management issues. However, if another exception is made, all animals should be vaccinated for rabies prior to release (Rosatte et al. 1992b); otherwise there is a danger of artificially spreading rabies as has been reported previously (Jenkins and Winkler 1987). Ear-tagging would help monitor their movements post-release.

In addition, Raccoons in Florida have become an example of an abundant native vertebrate that impacts the conservation of endangered species (e.g., Garrott et al. 1993) as they cause substantial destruction of sea turtle nests in Florida and throughout the southeastern United States (Stancyk 1982; Engeman et al. *in press*), as well as to shore-nesting birds such as terns and skimmers (Rodgers et al. 1996; Thompson et al. 1997). High density urban Raccoon populations in close proximity to beaches where nesting takes place may provide a reservoir of animals that artificially intensifies predation (Engeman et al. *in press*), and requires predator management to reduce their negative impacts (e.g., Reynolds and Tapper 1996; Hecht and Nickerson 1999).

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Notes

Initial Beneficial Effects of Fire and Bulldozing on Neglected Milkvetch, *Astragalus neglectus*, in an Eastern Ontario Alvar Woodland

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Catling, Paul M., and Adrianne Sinclair. 2002. Initial beneficial effects of fire and bulldozing on Neglected Milkvetch, *Astragalus neglectus*, in an eastern Ontario alvar woodland. Canadian Field-Naturalist 116(4): 640–642.

Following a fire 16 months earlier, data on presence and amount of a rare and restricted plant, *Astragalus neglectus*, was collected in order to determine the initial effects of burning and bulldozing. Frequency and cover were recorded in 340 one metre square quadrats of which 150 were in burned woodland, 90 were along the undriven portions of two bulldozed tracks through unburned woodland, and 100 were in unburned woodland. In addition, the number of *Astragalus neglectus* seedlings was recorded within 2.5 m of each of 450 observation points, each 5 m apart, including 150 along two bulldozed tracks and 300 in adjacent woodland. There were significantly more occurrences of *Astragalus neglectus* in burned woodlands and bulldozed tracks than in adjacent unburned woodlands. More than 95% of the *Astragalus neglectus* plants recorded were definitely seedlings, and the percentage seedlings may have been as high as 99%. A major spread and population increase in *Astragalus neglectus* is therefore associated with the recent disturbance events. This provides additional accumulating evidence that disturbance management may be important in maintaining high native biodiversity and rare species in alvar landscapes.

Key Words: alvar, limestone, fire, flora, biodiversity, diversity, rare species, succession, management, biomass removal, burn, burning, bulldozing, Great Lakes, Ontario, Canada

Neglected Milkvetch (*Astragalus neglectus* (Torr. & A. Gray) E. Sheld.) is considered rare to uncommon in Ontario (S3, Newmaster et al. 1998) and is a rare plant locally and regionally in the Ottawa valley where it has a relatively large number of occurrences (Brunton 1986*; Brownell and Larson 1995*, Brunton 1997*). Over 70% of the Ontario locations for this plant are in alvar landscapes (Catling and Brownell 1995; Brownell and Riley 2000) where the plants grow in open or semi-open locations on thin soil over limestone rock (Catling 1995). A year after a fire on the Burnt Lands alvar northwest of Ottawa in eastern Ontario, it was noticed that burned alvar woodland and tracks bulldozed through unburned alvar woodland contained large numbers of young plants of Neglected Milkvetch. This observation profiled questions regarding the use of disturbance in management of alvars and protection of distinctive alvar flora.

Many plant communities of alvar landscapes are currently recognized as globally imperiled and alvars contain numerous rare species (Catling and Brownell 1999; Brownell and Riley 2000), but information to effectively manage these communities is currently inadequate. A few recent studies however have suggested that large scale biomass removal may significantly contribute to biodiversity protection (Catling and Brownell 1998; Catling et al. 2001, 2002). The objective of the work reported here was to determine the extent to which fire and bulldozing had an initial beneficial effect on Neglected Milkvetch in order to contribute to understanding of the effects of disturbance and develop appropriate management plans to maximize protection of biodiversity in alvar landscapes.

*see Documents Cited

Methods

Study area

The Burnt Lands alvar is located in the county of Lanark and the former Regional Municipality of Ottawa-Carleton (see Brownell and Riley 2000), now part of city of Ottawa, on the Smith's Falls Limestone Plain in eastern Ontario. The sites specifically studied are centred on 45.2559 °N, 76.1432°W, and detailed descriptions of the actual positioning of transects are on file with the Kemptville office of the Ontario Ministry of Natural Resources.

On 23 June 1999, 152 ha of alvar woodland in the Burnt Lands was burned during a major fire. Dry conditions in the relatively shallow soil over porous limestone rock probably led to a relatively slow return to a mixed boreal and fire prone forest type

following the last fire in 1870. It seems likely that fire and post-fire succession has been going on in the area for many hundreds (or thousands) of years.

The study area (White 1979; Brunton 1986*; Brownell and Riley 2000) included burned and unburned alvar woodland dominated by Northern White Cedar (*Thuja occidentalis* L.), White Spruce (*Picea glauca* (Moench) Voss), Balsam Fir (*Abies balsamea* (L.) Miller), White Pine (*Pinus strobus* L.), and Quaking Aspen (*Populus tremuloides* Michx.). In order to contain the fire, accessibility was improved by bulldozing tracks which resulted in scraping of the shallow, often gravelly soil to 1 dm deep, with organic material, into piles sometimes with woody debris including broken trees and branches. Where the disturbance to soil as a result of scraping was minimal there was still compaction and removal of all woody plants. In general, the flatness made development of a system of tracks for fire-fighting very easy.

Since the plants were without flowers we used leaf pubescence to distinguish species. *Astragalus neglectus* has leaves that are glabrous above while *A. canadensis* has leaves that are hairy above. This difference appears to be a satisfactory discriminator based on examination of 30 correctly identified flowering specimens of each species collected throughout Ontario (in the Agriculture and Agri-food Canada herbarium (DAO) in Ottawa). Although *A. canadensis* was abundant along one track, it was confined to an area of approximately 100 m^2 and was not found in either the burned or unburned woodland.

Sampling procedures

The sampling was done in October 2000. The sampling time greatly facilitated the observation of *Astragalus* spp. because they remained green after the first few autumn frosts when many other species that they occurred with (*Aster macrophyllus* etc.) had turned brown. The sampling procedures involved (1) quadrats and (2) observation points:

(1) 340 one-metre-square quadrats, 5 m apart, were laid out along transects in three examples of burned woodland (50 quadrats each), along the undriven portions of two bulldozed tracks (45 quadrats each), and in examples of two unburned woodland (50 quadrats each). The sampled unburned woodland was 10 to 500 m from the burned and bulldozed sampling sites and at similar elevation. It was evidently of the same composition (see above) based on the identity of the burned or bulldozed trees. Data included presence and cover of *Astragalus neglectus* in all quadrats.

(2) the number of seedling *Astragalus neglectus* was recorded within 2.5 m of each of 450 observation points each 5 m apart. Of these observation points, 150 were along two bulldozed tracks and 300 were along transects in the adjacent woodland on either side of these bulldozed tracks, but 10 m from the edge. This latter distance ensured that the effect of bulldozing was not a factor relating to occurrence in the woods, but was near enough to the track to minimize the effect of other factors such as soil depth and moisture content.

Yates' corrected Chi-square was used to evaluate significance since 2 × 2 tables were used. Mean frequencies provided expected values.

Results

More than 95% of the *Astragalus neglectus* plants recorded were definitely derived from seed that germinated earlier in the year. Frequency of occurrence of *Astragalus neglectus* plants in burned woods was 25.33% (38) and along bulldozed tracks was 17.7% (16), compared to 1.3% (2) in unburned woodland. These differences are significant (Chi-square 0.001, 0.009 respectively). Cover in quadrats in burned woodland was 145 dm^2, along bulldozed tracks 49.5 dm^2 and was 0.5 dm^2 in unburned woodland. Adjustments of these total cover values for 100 quadrats are 96.6, 55.0 and 0.5 dm^2.

Astragalus neglectus was recorded at 41.66 % (61) of observation points along bulldozed tracks and at 1.66% (5) of observation points in unburned woodland. These differences are significant below the 0.0001 level. Only seven *Astragalus neglectus* seedlings were recorded in the unburned woods, but 1177 seedlings were recorded at the 61 observation points along bulldozed tracks.

Discussion

The significantly higher occurrences of *Astragalus neglectus* in burned woodlands and bulldozed tracks than in adjacent unburned woodlands suggest an initial beneficial effect of burning and bulldozing. The high percentage of this perennial plant, which was a result of seedlings in newly created habitat, indicates a major spread and population increase in *Astragalus neglectus* following the recent disturbance events. This spread and increase may be promoted by reduced competition for seedlings and/or increased nutrients leading to increased fecundity of survivors and increased survival of seedlings. In addition disturbance may be necessary to promote seed germination.

Astragalus neglectus was highlighted as one of a number of rare species occupying a floristically rich area of the Burnt Lands that had been burned 37 years earlier (Catling and Brownell 1998). The data presented provide more substantial evidence for the importance of disturbances such as fire and bulldozing in alvar landscapes, and the importance of transitional disturbed plant communities such as successional alvar burns. Maintenance of both maximum native biodiversity and rare species like *Astragalus neglectus* on alvars will probably require disturbance management techniques. Only recently has the potential dependence on disturbance by a portion of

the alvar flora and fauna been adequately recognized. However, parts of all Ontario alvars studied in depth have been burned, and burning is a natural process, so these conclusions are not surprising.

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Successful Spawning by Chinook Salmon, *Oncorhynchus tshawytscha*, in the St. Lawrence River at Cornwall, Ontario

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Between 26 October and 3 November, 2000, I observed Chinook Salmon (*Oncorhynchus tshawytscha*) spawning in a human-made creek entering the St. Lawrence River at Cornwall, Ontario. During the following spring and summer I searched for signs of successful spawning by conducting visual searches supplemented with regular seine netting. I captured young-of-the-year Chinook Salmon on four separate occasions, between June and September 2001. This is the second published report of successful spawning by Chinook Salmon in the St. Lawrence River and the first to identify a successful spawning location.

Key Words: Chinook Salmon, *Oncorhynchus tshawytscha*, spawning, St. Lawrence River, Cornwall.

Chinook Salmon (*Oncorhynchus tshawytscha*) are native to the west coast of North America (Hart 1973) but have been introduced to the Great Lakes on several occasions, dating back to the late 1800s (MacKay 1969; Scott and Crossman 1973). These repeated introductions have failed to produce a self-sustaining Chinook population in the Great Lakes, and although Chinook are now widespread through-

out the Great Lakes-St. Lawrence River, they require continued stocking to maintain a sport fishery (MacKay 1969; Scott and Crossman 1973; Hubbs and Lagler 1974).

In the St. Lawrence River, Chinook Salmon are occasionally captured by anglers, but there are no known spawning locations on the Ontario side of the river. Ribey and Chapleau (1996) captured young-of-the year Chinook Salmon while seining in the littoral zone of the St. Lawrence River near Cornwall, Ontario. Based on the small size (36.8 and 42 mm) of the two individuals they captured, they concluded that the fish represented local spawning by Chinook Salmon (Ribey and Chapleau 1996).

Here, I extend the observation of Ribey and Chapleau (1996) by identifying a Chinook spawning site in the St. Lawrence River at Cornwall. My observations include records of fall spawning behaviour by pairs of adult Chinook Salmon, capture of gravid females, and the presence of young during the following spring, summer and fall.

On three separate occasions, between 26 October 2000 and 3 November 2000, I observed adult Chinook Salmon in a human-made creek near downtown Cornwall, Ontario (45°00′45″N; 74°44′00″W). The 200 m long creek originates at the old Cornwall Canal and meanders though the Rotary Eco Garden for Conservation and Recreation before entering the St. Lawrence River. The creek and the surrounding naturalized areas were constructed, in 1997, during the implementation of the Remedial Action Plan for the St. Lawrence River Area of Concern (Dreier et al. 1997). The creek (Figure 1) varies in depth from about 0.2 to 0.8 m, and in width from about 4 to 6 m. At the upstream end of the creek there is a small waterfall that prevents the further upstream migration of fish into the Cornwall canal. The substratum of rounded cobble and gravel, and the meander radii were designed to mimic a natural stream with alternating shallow riffle areas and deeper pools. The water in the canal, which serves as the source of the water for the creek, originates as a small diversion from the St. Lawrence River near the Moses- Saunders power dam and therefore water quality in the creek is similar to that of the St. Lawrence River. Mean (± s.d.) monthly temperatures °C in the creek were: April, 6.8 ± 2.1(n = 6); May, 12.8 (n = 1); June, 18.0 ± 4.6 (n = 3); July, 22.0 ± 0.9 (n = 3), August, 23.7 (n = 1).

The adult salmon I observed were identified as Chinook based on their large size and the spotted

FIGURE 1. Human-made creek at the Rotary Eco Garden for Conservation and Recreation in Cornwall, Ontario. Spawning behaviour of Chinook Salmon was first observed in October 2000 in the area under the bridge shown in the photograph

pattern on the dorsal and caudal fins (Scott and Crossman 1973; Hart 1973). One individual, which I captured with a dip net, measured approximately 90 cm in total length. On two visits to the creek I observed pairs of Chinook engaged in spawning activity (excavating nests, swimming side-by-side), and one dead female Chinook with eggs (presumably killed by vandals) found by a City of Cornwall staff member.

To determine whether spawning was successful, I conducted regular searches (1–6 searches per month) of the creek between May and September 2001. These visual searches were supplemented with seine netting once or twice per month.

On four separate occasions I captured young-of-the-year Chinook Salmon. On 14 June 2001, I captured a single Chinook. On 27 June 2001, I captured a second individual which was preserved as a voucher specimen and deposited in the collection of the Canadian Museum of Nature (catalogue number CMNFI 2001-0055). On 16 July 2001, I captured three specimens, and on 25 September 2001, I captured an additional 11 Chinook Salmon.

Specimens were identified using the keys and descriptions in Scott and Crossman (1973) and Hart (1973). The identity of the voucher specimen was confirmed by Sylvie Laframboise and Claude Renaud of the Canadian Museum of Nature (Ichthyology). The pigmentation around the edge of the adipose fin and 10 long broad parr marks were distinctive of young Chinook Salmon. The total length of the voucher specimen was 57 mm.

To minimize the stress to the fish I returned the salmon to the water as quickly as possible and did not take measurements of individual fish; however, the 11 fish I captured on 25 September 2001 were approximately 100–150 mm in total length (Figure 2).

FIGURE 2. One of 11 young-of-the-year Chinook Salmon captured on 25 September 2001 in the creek at the Rotary Eco Garden for Conservation and Recreation in Cornwall, Ontario.

This is the first documentation of a location of successful spawning by Chinook Salmon in the St. Lawrence River basin. The precise origin of the young-of-the-year Chinook Salmon reported by Ribey and Chapleau (1996) is unknown, but it could not have been the creek that I describe here, since their observations were made before the Rotary Eco Garden and creek were constructed. Chinook Salmon runs occur in several of the tributaries on the U.S. side of the St. Lawrence but their success has not been documented (S. Lepan; New York Department of Environmental Conservation, Cape Vincent Fisheries Station, personal communication). The results I report here, along with those of Ribey and Chapleau (1996), suggest that natural reproduction by Chinook Salmon in the St. Lawrence River may be more widespread than previously thought. Whether the spawning frequency and success rates are sufficient to result in a self-sustaining population of Chinook requires more detailed information.

Acknowledgments

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Over-wintering and Reproduction by the Big Brown Bat, *Eptesicus fuscus*, in New Brunswick

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The first evidence of over-wintering and reproduction by the Big Brown Bat, *Eptesicus fuscus*, in New Brunswick is documented based on 24 new specimens and other reports from southern New Brunswick. Previously, this species was known in New Brunswick from three specimens and several unverifiable sightings. New distributional records, combined with echolocation surveys, suggest that *E. fuscus* is an insignificant component of forested ecosystems along the Fundy coast of central New Brunswick. In New Brunswick, the Big Brown Bat appears to be closely associated with human-occupied buildings. New Brunswick data support a previous suggestion that such behaviour may have promoted a northward range expansion by *E. fuscus*, and perhaps an increase in populations in more northerly regions.

Key Words: Big Brown Bat, *Eptesicus fuscus*, behaviour, distribution, hibernation, reproduction, New Brunswick

The Big Brown Bat, *Eptesicus fuscus*, reaches the northern limit of its eastern North American range in southern New Brunswick (van Zyll de Jong 1985). Although Morris (1948) stated that the Big Brown Bat occurred in New Brunswick, the presence of *E. fuscus* in the province was not confirmed until 4 September 1959 when a specimen was collected at St. Andrews, Charlotte County (Gorham and Johnston 1962). Squires' (1968) synopsis for the species in the province included only this single specimen and an indirect reference to an observation by S. W. Gorham. Subsequently, two additional specimens have been collected at Saint John, St. John County, 3 September 1976 and near Mactaquac, York County, on 4 September 1982. There is also a report of a Big Brown Bat echolocation sequence from Fundy National Park. (Tremblay 1989*, 1992) and several unsubstantiated sight records from various southern New Brunswick locations dating from 1930 to 1995 (Appendix 1; Squires 1967; Christie 1986). Sight records are based on bats observed roosting in a barn, in flight, or removed from mist nets during bird banding operations.

Until now, there has been no indication that the Big Brown Bat reproduced in New Brunswick. Also, in spite of extensive searches of New Brunswick bat hibernacula in caves and abandoned mines there have been no observations (McAlpine 1983) of this bat species over-wintering in the province. Here we compile 39 reports, both published and unpublished, for the Big Brown Bat in New Brunswick. These reports include 24 new specimens, plus two additional observations verified with archived photos and measurements. Most of the new data presented here has been collected incidental to ongoing monitoring programs for rabies.

There are five cases of the Big Brown Bat over-wintering in New Brunswick. Four of these bats, and

* see Documents Cited section

possibly the fifth, were all discovered moving about inside heated buildings between December and 23 March 1996–2001; NBM files, NBM 5796, 5821, 5936). Among the 24 new specimen records is a non-volant, near hairless, young collected from a building in Fredericton, 22 June 1999 (NBM 5792). A home in Central Hampstead, Queens County, also appeared to support a maternity colony under the metal flashing covering the roof of a 19th century farmhouse. One of the bats (NBM 5797) taken at this site, although well-furred, has a forearm length of 36.1 mm well below the range for adults of the species cited by van Zyll de Jong (1985).

Until recently, *E. fuscus* was known primarily as a cave or mine hibernator. However, Whitaker and Gummer (2000) suggest that prior to European colonization of North America, the Big Brown Bat hibernated mainly in hollow trees, and that this has pre-adapted the species to exploit buildings. New evidence shows that the hibernacula of choice for this species in Indiana are the attics of heated buildings (Whitaker and Gummer 1992; Whitaker and Gummer 2000). Whitaker and Gummer (2000) propose that historically the Big Brown Bat was limited to a more southerly range due to a dependence on hollow trees for hibernation, but recent use of heated buildings may have allowed the species to extend its range northward and to increase populations in more northerly areas. However, Whittaker and Gummer (2000) found that most buildings serving as hibernacula harboured very few bats ($\bar{x}$ = 2.7 bats for buildings which did not serve as summer maternity roosts). Brigham (1987) has reported that *E. fuscus* discovered active in buildings during winter in Ottawa weighed less and had significantly shorter forearm lengths than inactive bats hibernating in caves. The short mean forearm length of active bats studied by Brigham (1987) indicates that many were juveniles. He hypothesized that *E. fuscus* may become active in winter when energy reserves are critically low. While this suggests that active bats may not be those which will survive the winter in these buildings, two of our records came from the same building five years apart, suggesting long-term use of the site and successful over-wintering by some individuals.

Records presented here provide the first evidence of *E. fuscus* as a reproducing and over-wintering species in New Brunswick. While uncommon, the Big Brown Bat appears to be more abundant in New Brunswick than documented previously. With few Big Brown Bats in buildings, it is possible that the species has been overlooked in the past in New Brunswick. However, there have been an increasing number of bats submissions from New Brunswick for rabies testing since 1987 (6 in 1987, a high of 48 in 2001), the source for most of the recent Big Brown Bat data for the province presented here.

Only about 30 echolocation sequences from nearly 160 000 collected in and around Fundy National Park show characteristics that suggest these sequences are either Big Brown or Silver Haired Bat (*Lasionycteris noctivagans*) (H. Broders, University of New Brunswick, unpublished). Likewise, bat surveys in central forested and southwestern coastal Nova Scotia show the Big Brown Bat to be virtually absent in these areas (Broders et al. *in review**). Also, Zimmerman and Glanz (2000) captured only four *E. fuscus* in 840 mist net hours along the forested central Maine coast. While it appears that *E. fuscus* is an insignificant component of forested ecosystems along the central Fundy coast of New Brunswick, targeted surveys for this species are lacking. In particular, there is a need to carry out echolocation surveys in tolerant hardwood stands in southwestern New Brunswick, where large trees (> 50 cm DBH) that might provide rooting sites are present, or at likely feeding areas nearby. In New Brunswick the Big Brown Bat reaches a northern range limit, where it appears to be closely associated with human-occupied buildings. This supports the suggestion by Whittaker and Gummer (2000) that such behaviour may have promoted a northward range expansion by *E. fuscus*, and perhaps an increase in populations in more northerly regions.

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Appendix 1. Date, location, and source for records for the Big Brown Bat, *Eptesicus fuscus*, in New Brunswick.

*Bats verifiable by a specimen, or a photograph accompanied by measurements, deposited in the New Brunswick Museum (NBM) or Canadian Museum of Nature (CMN) collections.

[1] Bats submitted to Animal Disease Research Institute, Ottawa for rabies testing. Big Brown Bats submitted for testing prior to 1996 cannot be verified with specimens; however, at least four of the five animals were identified by a technician experienced in identifying Canadian bats.

Minimally, each of these records is documented in files housed at the NBM.

July 1930, Browns Flat, Kings County, NBM files.

*4 September 1959, nr. St. Andrews, Charlotte County, CMN 27731

October 1967, Westfield area, Kings County, Squires (1967)

*3 September 1976, Saint John, St. John County, NBM 1347

*4 September 1982, Mactaquac, York County, NBM 1887

1985[1], Moncton , Westmorland County, NBM files

27 October 1985, Grand Manan, Charlotte County, Christie (1986)

23 June 1987[1], Moncton, Westmorland County, NBM files

11 August 1987[1] , Fredericton, York County, NBM files

21 August 1988, Fundy National Park, Albert County, Tremblay (1989)

20 July 1988[1], Sackville, Westmorland County, NBM files

*? February 1990, Fredericton, York County, NBM files

12 July 1991[1], Fredericton, York County, NBM files

25 September 1995, Kent Island, Charlotte County, NBM files

*15 July 1996[1], Fredericton, York County, NBM 5933

*December 1996, Fredericton, York, County, NBM files

*24 July 1997, Central Hampstead, Queens County, NBM 5793

*24 July 1997[1], Central Hampstead, Queens County, NBM 5794

*24 July 1997[1], Central Hampstead, Queens County, NBM 5795

*24 July 1997[1], Central Hampstead, Queens County, NBM 5797

*15 January 1998[1], St. Andrews, Charlotte County, NBM 5796

*6 August 1998[1], Saint John, Saint John County, NBM 5825

*22 June 1999[1], Fredericton, York County, NBM 5792

* 2 July1999[1], Central Hampstead, Queens County, NBM 5823

* 2 July1999[1], Central Hampstead, Queens County, NBM 5935

*14 July 1999[1], Fredericton, York County, NBM 5791

*15 February 2000[1], Fredericton, York County, NBM 5821

*18 July 2000[1], Fredericton, York County, NBM 5820

* 30 August 2000[1], Lincoln, York County, NBM 5819

*23 March 2001[1], Fredericton, York County, NBM 5936

*8 June 2001[1], Harvey, York County, NBM 5937

*20 June 2001[1] , Islandview, York County, NBM 5938

*25 June 2001[1], St. Stephen, Charlotte County, NBM 5939

*29 June 2001[1], Central Hampstead, Queens County, NBM 5934

*20 August 2001[1], St. Stephen, Charlotte County, NBM 5940

*4 September 2001[1], Moncton, Westmorland County, NBM 5951

*8 August 2002[1], Sussex, Kings County, NBM 5952

*14 August 2002[1], Fredericton, York County, NBM 5953

*21 August 2002[1], Black's Harbour, Charlotte County, NBM 5954.

Behavioral Modification of Gray Wolves, *Canis lupus*, Suffering from Sarcoptic Mange: Importance of Sequential Monitoring

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Shelley, Douglas P., and Thomas M. Gehring. 2002. Behavioral modification of Gray Wolves, *Canis lupus*, suffering from sarcoptic mange: Importance of sequential monitoring. Canadian Field-Naturalist 116(4): 648–650.

We documented the behavioral patterns of two disease-stricken Gray Wolves (Canis lupus) in northwestern Wisconsin and east-central Minnesota by means of radio telemetry. Our observations suggest that the modified behaviors of these wolves were integrally linked to the increased loss of thermal energy due to severe hair loss and sarcoptic mange mite and biting louse infestations. We believe that sequential monitoring using radio telemetry allowed the identification of these behavioral patterns. Wildlife managers might use frequent monitoring to identify disease-stricken animals and implement proactive measures to counter some wildlife diseases.

Key Words: *Canis lupus,* Gray Wolf, disease, behavior, mortality, radio telemetry, sarcoptic mange, Wisconsin, Minnesota.

Radio telemetry is a useful technique for gathering data on wide-ranging and cryptic wildlife species. Recently, several researchers have debated the question of independence in radio locations (Swihart and Slade 1985a, 1985b, 1997). Swihart and Slade (1997) reiterated the importance of independent radio locations (e.g., for some habitat selection analyses), but also pointed to the importance of sequential observations for behavioral studies. Herein, we report on the modified behavior of Gray Wolves (Canis lupus) suffering from sarcoptic mange as determined by means of sequential monitoring. We suggest that frequent monitoring may assist managers in the early detection of disease in recovering wolf populations.

Methods

Wolves were captured in east-central Minnesota and northwestern Wisconsin during May-August in modified #14 Newhouse steel traps (Kuehn et al. 1986). Captured wolves were immobilized by means of an intra-muscular injection of ketamine hydrochloride and xylazine hydrochloride. Once immobilized, wolves were fitted with a radio-collar and ear-tagged with a uniquely numbered plastic tag (Kohn et al. 2000). During October 1992-January 1993, we monitored the movements of individuals from the Truck Trail pack (TTP) using a vehicle-mounted radio telemetry unit (Gehring 1995; Shelley and Anderson 1995). The TTP consisted of four wolves, three of which were radio-tagged, including: 131M (adult male, captured 21 August 1991, capture weight = 44.9 kg), 203F (adult female, captured 29 July 1992, capture weight = 30.8 kg), and 133F (yearling female, captured 22 August 1991). Wolf 133F dispersed from the TTP in December 1992. The body weight of W203F was comparable to the mean body weight for adult female wolves in our study area ($\bar{x}$ = 30.2 kg, n = 4; Gehring 1995), whereas the body weight of W131M was greater than the mean body weight for adult male wolves in our study area ($\bar{x}$ = 37.1 kg, n = 7; Gehring 1995). Only wolves 203F and 133F radio collars were equipped with mortality sensors (Garshelis et al. 1982). Wolves 203F and 131M were relocated by triangulation (Heezen and Tester 1967) 1-2 times daily and hourly during sequential tracking sessions. Radio locations obtained > 4 h apart were considered independent (Swihart and Slade 1985a, 1985b, 1997). Sequential tracking sessions were conducted for 6-8 hours, approximately 4-6 times/month. Additionally, we recorded the activity of wolves by noting changes in pulse rates (Garshelis et al. 1982).

Results and Discussion

During the study period, we collected 107 and 102 independent locations for 203F and 131M, respectively. The time between locations ranged from 4-48 h (203F) and 4-120 h (131M). We relocated these two wolves together during 24% of the October locations, 8% of the November locations, 5% of the December locations, and none of the January locations. Conversely, we found that wolves maintained high pack cohesion in three neighboring packs that we monitored concurrently (Gehring 1995). We found that both wolves concentrated their movements to four areas within the TTP territory (33% of 203F and 37% of 131M locations), but these individuals largely used these areas independently of one another. Two of these sites contained carrion; we found a Beaver (*Castor canadensis*) and Mink (*Mustela vision*) carcass pile left by trappers at one site, and two to three carcasses of White-tailed Deer (*Odocoileus virginianus*) killed by wolves in December at the other site. We recorded numerous visits and wolf bedding areas at the latter site. The third site contained no obvious food source, and the fourth was considered a non-food area until January

*see Documents Cited

when the remains of a freshly-killed White-tailed Deer were found. We believe that 203F made this kill with another wolf based on wolf tracks present and our telemetry record.

From 23 December 1992 to 13 January 1993, 203F exclusively traveled a network of improved dirt roads, plowed and unplowed. A total of 26 independent locations were obtained during this period. Of these, 5 (19%) were recorded in mortality mode (i.e., the animal had not moved in 5-6 h). After 203F was initially located, she would remain in mortality mode for an additional 4-27 h (determined by sequential locations). On 13 January 1993, 203F was located in a local resident's garage. She was immobilized and transported to a local wildlife health clinic for ectoparasite treatment on 14 January, but died later that night. Necropsy results indicated that the primary cause of death was a subcutaneous fistula leading to pyothorax (Thomas 1993a*). An abscess in the muscles of the right thoracic region was centered around an embedded Porcupine (*Erethizon dorsatum*) quill and was estimated to be several weeks old. The Porcupine quill may have become embedded in 203F if she was scavenging or rolling on a Porcupine carcass (Mech 1973), or the remote possibility of her preying on the Porcupine (not found in the literature). Wolf 203F was suffering from severe infestations of sarcoptic mites (*Sarcoptes scabiei* var. *canis*) and biting louse (*Trichodectes canis*) and approximately 35% hair loss (Thomas 1993a*), indicating moderately severe alopecia (Bornstein et al. 2001). Wolf 203F's carcass weight, 27.4 kg, was 11% less than her capture weight.

From 1-26 January 1993, the 24 locations obtained on 131M indicated that he restricted his movements to an approximately 5 ha area. Unfortunately his collar was not equipped with a mortality sensor. However, 15 of 131M's January locations were recorded in inactive mode (Kenward 1987), but he was believed to move between locations due to noticeably different UTM locations. Radio locations suggested that 131M did not move from 22-26 January 1993 (no discernable UTM difference). Wolf 131M was found dead on 27 January 1993, buried under 20-25 cm of snow. Wolf 131M's time of death was estimated to be between 20-26 January 1993 based on snow fall data (snow fall recorded on 12-14 January and 22-26 January 1993) and telemetry locations. Necropsy diagnostic results indicated cold exposure as the primary cause of death (Thomas 1993b*). W131M had severe infestations of sarcoptic mange mites and biting lice. Approximately 50-75% of 131M's body hair was missing (Thomas 1993b*), indicating severe alopecia (Bornstein et al. 2001). Wolf 131M's carcass weight was 43.0 kg, a 4% decrease in weight from his capture date.

Todd et al. (1980) documented that mangy wolves in Alberta had body weights 4-10% lower than non-mangy wolves. Wolves with advanced cases of mange were 22% below the average weight for adults (Todd et al. 1980). In terms of body condition (based on loss of body weight), W203F appeared to be in the poorest body condition resulting from a moderately severe case of mange, whereas W131M appeared to have slightly better body condition based on a 4% loss of weight.

We observed behavioral patterns in wolves 203F and 131M which appear to differ from wolf behavior stereotyped as normal behavior (sensu Mech 1970). Both collared wolves appeared to increase scavenging behavior during October-January. For wolves, behavioral shifts to increased scavenging are generally associated with low prey availability or illness (Mech 1973; Todd et al. 1980). However, deer and Beaver abundance was high in the TTP (Gehring 1995; Shelley and Anderson 1995). Trainer and Hale (1969) observed mangy Coyotes (*Canis latraus*) that demonstrated abnormal behavior including listlessness and loss of fear of man. Similarly, Todd et al. (1980) suggested that mangy coyotes tended to be more dependent on carrion compared to non-mangy coyotes. Thus, the apparent increased use of carrion by the two wolves in our study suggests that mange was the causal factor leading to these increased scavenging.

Increased dependence on carrion, concentrated movements, extended periods of inactivity (by both wolves), immobility defined by the mortality sensor, and exclusive travel on roads suggests that these wolves were in poor physical condition. We suggest that this weakened physical state and modified behavior was integrally linked to the increased loss of thermal energy due to severe hair loss and sarcoptic mange mite and biting louse infestations. We believe that sequential observations allowed us to identify these behavioral modifications. Furthermore, we suggest that managers might use sequential radio locations and frequent monitoring to define dramatic shifts in behavioral patterns, particularly in recovering populations (e.g., Wisconsin Department of Natural Resources 1999*). Such shifts may be used as an indicator of disease-stricken animals and may allow proactive treatment of wildlife diseases.

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Book Reviews

ZOOLOGY

The Birds of British Columbia Volume 4: Passerines [:] Wood-Warblers through Old World Sparrows

By R. Wayne Campbell, Neil K. Dawe, Ian McTaggart-Cowan, John M. Cooper, Gary W. Kaiser, Andrew C. Stewart, and Michael C. E. McNall. 2001. UBC Press, Vancouver, British Columbia. 741 pp., illus. $125.00.

This hefty tome completes a series inaugurated in 1990 (see reviews of the first two volumes in *Canadian Field-Naturalist* 107: 547-548, 1993 and of volume 3 in *Canadian Field-Naturalist* 115: 187-188, 2001). The bulk of the book (pp. 9-617) consists of accounts of species not covered in the first three volumes. These cover 101 species in seven passerine families (Parulidae: wood-warblers, Thraupidae: tanagers, Emberizidae: New World sparrows and allies, Cardinalidae: some grosbeaks, some buntings and Dickcissel, Icteridae: blackbirds, orioles and allies, Fringillidae: Cardueline finches and allies, and Passeridae: Old Word Sparrows). A second major section (pages 619-629) consists of mini accounts of 28 species that have been documented as occurring within British Columbia or as breeding within the province since the publication of the first two volumes (non-passerines), not the first three as stated on page 620. A final major section consists of a two-chapter synopsis (pages 631-695). Additional introductory and closing sections include a detailed, four-page acknowledgement of significant contributions as well as a six-page list of 3629 (!) contributors of records, a list of references cited, a brief index, and brief biographical details of the authors and of four additional "contributing" authors, who wrote sections of volume 1 (Dennis A. Demarchi) or of this volume (Richard R. Howie, Chris Siddle, and Linda M. Van Damme). Four data appendices were omitted from the book for space reasons, but are available on the World Wide Web for interested readers who have access to the internet. A brief tribute by his co-authors to Ian McTaggart-Cowan's contributions to British Columbia ornithology over his first 90 years concludes the book.

As in the first three volumes, species of "regular" occurrence receive more coverage than in many other regional avifaunal works of recent decades. These accounts encompass three to 17 pages each, with text on range (generally in the world), status in British Columbia, nonbreeding and breeding status, distribution and chronology in the province, nesting details if the species breeds in British Columbia (with details on nests, eggs, young, degree of Brown-headed Cowbird parasitism [if any]), "remarks" (comments on taxonomy, range expansions/contractions, comments on questionable records, remarks on range and distribution of distinct races within the province, and numerous other biological tid-bits), and a selection of "noteworthy" records. The text is illustrated with colour photographs of the species, its habitat(s) in British Columbia, and sometimes nests, eggs, and/or young and with maps and graphs of distribution and chronology in various regions of this vast province with its complex range of habitats and climate. Additional graphs, maps, and tables in some species illustrate population trends, chronology of nesting in different regions, banding recoveries, a tabulation of known hosts of Brown-headed Cowbirds in British Columbia and other biological details. Relevant literature is cited throughout the text.

As in the previous volumes, species considered "casual, accidental, extirpated and extinct" in the province receive shorter accounts (about one-third to one page each). These 22 accounts consist of the world range of the species, its status in British Columbia, a list of occurrences accepted by the authors, and "remarks". Documentary photographs accompany ten of these accounts. The authors' desire to be as current as possible is exemplified by the addition in postscripts of occurrences of three of these species after the species accounts were written.

The section of addenda to non-passerine birds consists of brief accounts of six species (Clark's Grebe, Northern Fulmar, Upland and Baird's sandpipers, Franklin's Gull, and Black-legged Kittiwake) demonstrated to breed in British Columbia since publication of the 1990 volumes, as well as accounts of one species added to the province's avifauna by virtue of a taxonomic split (Pacific Golden-Plover), four species elevated from "hypothetical" to documented status (Black Vulture, Falcated Duck, Spectacled Eider, and Yellow Rail), and 17 species completely new to the provincial list.

The concluding "synopsis" consists of two chapters. The first, "avian biodiversity, ecological distribution, and patterns of change" is essentially a condensed analysis of ornithogeography in British Columbia, examining patterns of distribution (breeding, wintering, and migrant) in relation to geographic features, human activity, and other factors. These

emphasize changes in both distribution and populations in relation to various environmental changes. Such concepts as biodiversity, species richness, "hot spots" in which large numbers of birds concentrate, endemism, population trends, and species of varying degrees of concern are discussed with the aid of a rich array of tables and graphs. The final chapter is a realistically pessimistic look at the future of bird populations in British Columbia and the world generally, summarizing the role of human activity of all sorts (depletion of resources, altering of ecosystems, etc.) in putting ever-increasing stresses upon the environments on which birds and other life forms depend as human populations grow and the impacts imposed by individual humans escalate. Local and global solutions required to counteract these trends are also outlined.

The vast geographic expanse of British Columbia and its rich variety of habitats at varying elevations pose challenges to writing generalized accounts of birds that occur there regularly. The authors have handled this diversity well by noting status within various portions of the province, and charting such features as migration and egg-laying dates by region in text and/or in charts. Although knowledgeable readers of any specific account will quibble with omissions of specific details and/or references, the text is both more thorough than is usual in provincial or state bird books and well referenced. Emphasis is on British Columbia data when available, but specific details from elsewhere are cited frequently.

On the whole, the accounts of species that have strayed into British Columbia are also thorough and written well. When available, documentary photographs are included. The text places the British Columbia occurrence(s) in context with population trends and patterns of vagrancy elsewhere. The "remarks" sections of these species often include notes on additional records of the species that the authors have rejected because of lack of sufficient documentation or suspicions that the bird observed had escaped from captivity. Inclusion of such records will help observers assess future records of these species, some of which may seem more likely as patterns of vagrancy become apparent. Unfortunately, however, disagreement on the validity of records accepted by the authors is not mentioned. For example, a Xantus's Hummingbird that spent nearly a year at Gibsons is included without any mention that the record was rejected by the British Columbia Field Ornithologists Bird Records Committee on the grounds that it may represent a ship-transported bird. While many observers (including several of the committee members) agree with the authors in accepting this record, it would be useful to readers to know that the record is controversial. Similarly, no mention is made that one of the three records of White-tailed Kite accepted by the authors was rejected by the B.C. records committee, but accepted by the equivalent Vancouver committee.

The chapter on "avian biodiversity, ecological distribution, and patterns of change" is a thorough summary of distributional patterns and ongoing population and distributional changes within British Columbia of all the species covered in all four volumes. The text is enhanced by numerous tables, maps, and charts. *Canadian Field-Naturalist* readers will already be familiar with the many threats to bird populations (and ecosystems generally) outlined in the final chapter.

As in previous volumes, the list of references cited is extensive. Unfortunately, about 30-40 of the references cited in the text appear not to be in the list of references. Some of these probably result from mismatches between the dates indicated in the text and the dates of the corresponding listed references. The number of missing or mismatched references seems high for a book with so many authors. The final proof-reading appears not to have been performed by all of the authors. Perhaps the most significant omission is a reference by Stone to a male Sage Sparrow collected in Vancouver in 1899 and overlooked in previous works on British Columbia's avifauna. As in volume 3, the 1966 edition of *The birds of Alberta by* W. R. Salt and A. L. Wilk is listed as by W. R. and J. R. Salt.

Most of the errors in this volume consist of minor grammatical flaws (especially split infinitives), spelling of the names of some observers, and other minor glitches, rather than substantial mistakes. Like the three previous volumes, this final volume is a thorough compilation and analysis of what is known about British Columbia's avifauna to date and an excellent guide to many of the knowledge gaps that still exist.

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The Royal Ontario Museum Field Guide to Amphibians and Reptiles of Ontario

By Ross MacCulloch. 2002. Royal Ontario Museum and McClelland and Stewart Ltd., Toronto, Ontario. 168 pp., illus. $24.99

Ontario, with more than half of the over 90 species (native and introduced) of amphibians and reptiles recorded in Canada, was the first province to have its own guides to its amphibians (1937, Royal Ontario Museum Handbook 3) and reptiles (1939, Royal Ontario Museum Handbook 4). The author of these, E. B. S. Logier, artist and herpetologist at the ROM from 1915 to 1961, followed with books on amphibians of eastern Canada (1952, Clarke, Irwin & Company Limited) and snakes of Ontario (1958, University of Toronto Press). Since, there have been popular booklets on Ontario snakes and turtles in 1967 by Barbara Froom published by the Ontario Department of Lands and Forests (now Ministry of Natural Resources) and in 1989 a book, *Familiar Amphibians and Reptiles of Ontario* by Bob Johnson of the Metropolitan Toronto Zoo published by Natural Heritage/National Heritage Inc., Toronto. Detailed spot distribution maps for the province have been underway as the Ontario Herpetofaunal Summary (1986, 1988, 1989) edited by Michael J. Oldham and others, and now updated on a web site sponsored by the Natural Heritage Information Centre of the Ontario Ministry of Natural Resources www.mnr.gov.on.ca/NMR/nhic/herps/ohs.html.

Now comes a notching up in the standards of presentation by several orders of magnitude. *The ROM Field Guide to Amphibians and Reptiles of Ontario* is a blaze of colour photographs offset with brief and usefully structured information, truly a field-naturalist's book. What it lacks in detailed character or ecological discussions prevalent in earlier Ontario guides, it offsets by providing ease of identification through colour photographs and pruned accounts most useful for field use. The experience of the author is evident throughout. MacCulloch, now an assistant curator, has been active in herpetology at the Royal Ontario Museum since 1982 with research projects both in Ontario and abroad, and, previous to that, has conducted field studies in Quebec with Roger Bider of Macdonald College, McGill University, and obtained a M.Sc. on the Western Painted Turtle in Saskatchewan with Diane Secoy, University of Regina.

The organization and layout of the book are appealing. A brief Introduction sets amphibians and reptiles in context in natural systems. Characteristics covered are general features of reproduction, metamorphosis, skin, diet, and metabolism for amphibians and reproduction, eggs, skin, diet, and metabolism for reptiles. Treated next are The Challenge of Climate (winter, hibernacula, spring, summer and autumn); Observing Amphibians (oddly omitting frogs); Identification (appearance, habitat, season, adding to our understanding – with reference to data bases and surveys which need volunteers, and naturalists groups which conduct nature walks and field trips); Conservation (legal issues, amphibians and reptiles as pets – pointedly stressing that the regulations that exist on keeping native species as well as the difficulties with maintaining exotics argue against captives); and Amphibian populations in decline? – stressing their general resilience despite cases of localized extirpations of populations or species). Using This Book discusses the format of sections to follow on Comparative Photographs and of Species Accounts (and includes national (COSEWIC) and Ontario (OMR) species ranking definitions), and Distribution Maps. Further Information on Ontario Amphibians and Reptiles contains a list of selected books and other print sources and a list of internet sources which cover provincial and national parks in Ontario, other agencies and organizations, and Ontario natural history societies (even if you are not the least interested in amphibians and reptiles this is a handy reference for any naturalist). The book ends with a glossary of terms, a "Checklist of Ontario amphibians and reptiles", index, photo credits, and acknowledgments.

The bulk of the book lies in the user-friendly comparative photographs section (pages 25-32) and the species accounts (pages 25-32). The comparative photographs, effectively replacing written keys used in many other publications, are grouped by salamanders, frogs, turtles, and snakes (the one lizard, the only representative of its group, is omitted here) with one photograph and the Ontario distribution map in miniature for each species for quick contrast. The species accounts proper are equally adroitly designed and cover the 47 species (10 salamanders, 13 frogs, 8 turtles, 1 lizard, and 15 snakes) regarded as still occurring and native. For each species a page of three colour photographs of variants in colour, pattern, or life history stage is opposite a page giving introductory comment, appearance, habitat and behaviour, reproduction, and status. There is also a map of Ontario, and one of North American, distribution for each. The ranges are depicted as solid patches and the reader is directed to the Ontario Herpetofaunal Survey web posting for more detailed distribution maps, a reasonable approach assuming most field users will want approximate rather than detailed distributions (which would not work well in the pocket-sized format of the book). In addition to the full accounts, page 96 briefly gives a paragraph each to three salamanders and page 162 to two turtles and one snake regarded as extirpated (Tiger Salamander, Spring Salamander, and Timber Rattlesnake) or introduced (Red Salamander, Box Turtle, Red-eared Slider) to bring the total recorded

for Ontario to 53). Amphibians and reptiles as groups are each given, before the accounts of their included species, two pages outlining general characteristics. Each family within these is prefaced by a photographic portrait of a member of that group opposite a paragraph of text on group characteristics. An added convenience is a colour strip on the edge of each page of the comparative photographs and species accounts with topic captions along them, so the reader can flip the edges and rapidly find the account desired.

There are a few niggling details amiss to irritate the experienced herpetologist, inevitable in a book where the text is so concentrated and photographs are from varied contributors. Among omissions are the lack of specific mention in the Blue-spotted and Jefferson salamander accounts that hybrids may occasionally be tetraploid or higher ploidy and rarely are male, but this has been covered in the Ambystomatidae page that precedes them. There is no mention in the Red-backed Salamander account of the rare all-red (erythristic) phase without dark sides recorded from southern Ontario, an omission also imposed by space constraints in the single-page per species format. In accounts for Bullfrogs and Snapping Turtles the number of eggs is low, the former can produce more than 8000 eggs, and the latter more than 40. Brown Snakes often have pink or white undersides as pointed out in the text of that species, but only light brown is used to distinguish it from the Red-bellied Snake in the text of the latter. The scientific name of the introduced Eastern Box Turtle is *Terrapene carolina*, not *Terrapene ornata* as given on page 162. Although the photographs are generally vivid and outstanding for their purpose, occasionally they are atypically light as in the top Mink Frog on page 93 (in comparison with northern populations I have seen) or too dark to show detail as in the center Mink Frog on page 93 (where the hind leg markings are thus obscured and look more banded than blotched, a Green Frog character). Another possibly atypical example is the center photograph of Butler's Garter Snake on page 135 which looks very like a Common Garter Snake from eastern Ontario in the greenish yellow of its stripe and labial (lip) scale colouration, the trace of black rather than the broad chocolate margin beneath the lateral stripe, and the position of that stripe which does not seem to be significantly above scale row three except at the head. The Wood Frog pictures might usefully have included one with a mid-dorsal light line, a variant mentioned in the text. Northern Ontario populations can have quite high numbers of these striped individuals, a distinctive variant occuring only in this species among Canadian frogs. The Black Ratsnake pictures usefully could have included a blotched juvenile to contrast with the Milk Snake which occurs within its range (the Racer selections effectively do include a juvenile) and the Hognosed Snake selections could have included a black (melanistic) animal to contrast with the spotted phase shown. The very dark backgrounds used for tadpoles and salamander larvae are at first disconcerting but surprisingly effective (and the Grey Treefrog tadpole is outstanding). Some frog tadpoles are paler in colouration than I am used to in eastern Ontario, and it would have been useful for researchers to have had the locality of each specimen given for all photographs. The designers appear to have inverted two pictures (bottom of pages 107 and page 143).

Such flaws are inconsequential in the overall effect and general quality of the book. It deserves, and certainly will have, very wide sales and longevity. It is conveniently field-portable and has a place in every naturalist's pocket from eastern Manitoba to Prince Edward Island as, aside from the Spring and Mountain Dusky salamanders of the mountains of southern Quebec and the marine turtles of the Atlantic, it covers every species to be found in eastern Canada, and most of those in the northeastern United States. The author and the talented designers at the Royal Ontario Museum should be congratulated not only on the quality of this effort, but also in continuing a tradition of one of the things that a scientific staff of museums can do best – authoritative, accurate field guides.

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The Amphibians and Reptiles of Alberta: A Field Guide and Primer of Boreal Herpetology, Second Edition

By Anthony P. Russell and Aaron M. Bauer. 2000. University of Calgary Press, Calgary, Alberta. 280 pages, illus. $24.95.

This is a first in Canadian herpetological field guides, a second edition, and only seven years after the first appeared in 1993 (see review by James D. Gardner. 1994. *Canadian Field-Naturalist* 108: 379-380), a fine tribute to its initial success as both a field guide and introductory herpetological text, validating the judgement passed by the earlier reviewer.

It has the conventional species accounts of 18 doc-

umented species [10 amphibians (2 salamanders and 8 frogs and toads) and 8 reptiles (1 turtle, 1 lizard, and 6 snakes)] and four additional accounts of species that might occur in the province (1 frog, 1 turtle and 2 snakes). These numbers are unchanged from the first edition but the nomenclature has been updated as five species have undergone scientific name changes (*Scaphiopus bombifrons* to *Spea bombifrons, Pseudacris triseriata maculata* to *Pseudacris maculata, Rana pretiosa* to *Rana luteiventris; Phrynosoma douglassii brevirostre* to *Phrynosoma hernandesi, Pituophis melanoleucus* to *Pituophis catenifer,* and a sixth (*Ambystoma tigrinum*) is "in a state of flux" (page ix) and western populations have been designated *Ambystoma mavortium* but this has not been generally accepted, and is not followed here.

Research has continued on the herpetofauna in the interval between editions, particularly as part of the production of status reports on the wildlife of Alberta, eight of which to publication had dealt with amphibians and reptiles. As well, research on species that occur in Alberta has continued elsewhere in their ranges. References directly relevant to the herpetofauna of Alberta have increased by more than 150, and the text has been updated throughout to reflect this. In the species accounts a section on Conservation Status has been added. Errors in the first edition have been corrected, for example the first appearance of reptiles (page 13) is now pushed back to the Carboniferous Period (about 330 million years ago) from the Permian (260 million years ago) in the first edition. The spot distribution maps have been updated from the research for status reports and other publications since the previous edition. Particularly significant examples are additions of records of the Long-toed Salamander, *Ambystoma macrodactylum*, for the Peace River region and deletion of a perplexing record for the Tiger Salamander, *Ambystoma tigrinum*, north of 53°. Records for the Spadefoot Toad extend its range in eastern Alberta north to between 52 and 53° from 51°N. The Boreal Toad, *Bufo boreas*, has now been extended east at about 51°N, nearer to the Saskatchewan boundary. Other records expand the range of the Columbia Spotted Frog, *Rana luteiventris*, somewhat eastward and the Western Hognose Snake, *Heterodon nasicus*, marginally to the west. Some species, particularly the Great Plains Toad, *Bufo cognatus*, the Canadian Toad, *Bufo hemiophrys*, and the Leopard Frog, *Rana pipiens*, show many new localities within their previously known ranges.

The concluding overview text sections retain headings of zoogeography, natural history, coping with cold, the challenge of aridity, defense, and venoms. The concluding section, "Man and the herpetofauna" in the first edition, has been retitled "Amphibians, Reptiles, and People". New paragraphs updating conservation concerns have been inserted.

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Rare Amphibians, Reptiles, and Mammals of British Columbia

By Sydney G. Cannings, Leah R. Ramsay, David F. Fraser, and Mark A. Fraker. 1999. Lands and Parks, Wildlife Branch and Resource Inventory Branch, Ministry of Environment, Victoria, British Columbia. 190 pp., illus.

This coil-bound publication is a valuable resource summary reference that covers all native amphibian, reptile, and mammal species, subspecies or distinct populations that are included in the Red and Blue lists of species considered at risk in British Columbia. The information is stated to have been subjected to extensive technical review, but only contributors of information, not reviewers, are listed. Statements in the accounts are referenced to published scientific literature. The Red List includes those for which there is most concern, any indigenous species or subspecies extirpated, endangered, or threatened in British Columbia. The Blue List covers species or subspecies vulnerable in British Columbia, those judged particularly sensitive to human activities or natural events, and also species that are suspected of being vulnerable but for which current information is insufficient to designate them in another category. One declared use of the Red and Blue lists is "in the Forest Practices Code to identify endangered or threatened wildlife that require attention under forest development, silvicultural, and range use operational plans".

An introduction which gives definitions used and book's scope is followed by accounts for each taxon by group. Each section has its own reference list. Four appendices give the 1998 Red and Blue lists, the status of the listed taxa in adjacent jurisdictions, and the global and provincial ranking of vertebrates in British Columbia.

The 73 taxa accounts, 146 pages, include: 8 amphibians (3 salamanders and 5 anurans), 10 reptiles (2 turtles, 1 lizard, 7 snakes); and 55 mammals (4 shrews, 1 mole, 8 bats, 1 pika, 2 hares, 1 rabbit, 2 mountain beavers, 1 marmot, 1 ground squirrel, 4 chipmunks, 1 pocket gopher, 1 pocket mouse,

3 voles, 1 lemming, 1 harvest mouse, 1 jumping mouse, 2 bears, 1 sea lion, 1 Sea Otter, 2 wolverines, 1 Fisher, 3 weasels, 1 badger, 3 ecotypes of the Killer Whale, 1 porpoise, 1 elk, 1 caribou, 2 bison, 3 sheep (Bighorn and Thinhorn).

Each account gives paragraphs on Taxonomy, Status (Global, IUCN, COSEWIC, Provincial), Global Range, Ecoprovinces, Biogeoclimatic Zones, Biology, Global Ranking, Provincial Ranking (Rank and Comments), Range in British Columbia, Estimated occurrences, Abundance, Trend, Protected occurrences, Threats, and Conservation Needs (Research, Inventory, Management and Stewardship) and a map showing shaded distribution in British Columbia. The accounts are brief summary compilations from the literature, apparently with little new material. However, most statements have citations of source, allowing original studies and greater detail to be found. Most references refer to data from British Columbia populations. The usefulness of the maps is diminished, however, by failure to use dots showing documented localities.

The evaluation of threats section ocasionally seems generalized from the entire range and simply extrapolated to British Columbia without justification, for example in the Pacific Pond Turtle. On page 29 it is stated for it that "The major threats are loss of habitat through urban and agricultural development in the Lower Mainland, and the introduction of non-native predators." A surprisingly focused assessment when there are no British Columbia specimens of this species and the only two documented observations of it for the province, both in the 1930s, are from the city of Vancouver, with one additional vague undocumented "record" suposedly from 1966. Little useful purpose is served by even including a species on such evidence, let alone trying to guess threats. It was comonly marketed for food in its range to the south, and individuals reported were most likely imported escapes, rather than last survivors of a overstressed native population. No mention is made of two British Columbia turtle specimens collected in 1929 (Canadian Museum of Nature, 1525 from Alberni, and 1551 from Vancouver) of an Asiatic species, *Chinemys reevesii*, which clearly demonstrate the release or escape of turtles that were imported and marketed in both Victoria and Vancouver as is documented by Storer in Copeia 1937(1): 9-11.

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Scientific and Standard English Names of Amphibians and Reptiles of North America North of Mexico, with Comments Regarding Confidence in Our Understanding

By Committee on Standard English and Scientific Names, Brian I. Crother, Chair, Jeff Boundry, Jonathan A. Campbell, Kevin de Queiroz, Darrel R. Frost, Richard Highton, John B. Iverson, Peter A. Meylan, Tod W. Reeder, Michael E. Siedel, Jack W. Sites Jr, Travis W. Taggart, Stephen G. Tilley, and David B. Wake. 2000. Society for the Study of Amphibians and Reptiles, Herpetological Circular Number 29. 82 pp. [Available from SSAR Publications Secretary, Robert D. Aldridge, Department of Biology, Saint Louis University, St. Louis, Missouri 63103 USA; e-mail: ssar@slu.edu]. U.S. $10.00.

The drive to standardize common names for North America amphibians and reptiles has been strong in herpetology for the past 50 years, the one to compile checklists of accepted scientific names has been longer, 85 years. Combined, they are still very much a work in progress. The process of compiling the accepted scientific names in a checklist reflecting the opinions of a cross-section of herpetologists rather than that of a single expert was begun in 1917 by Leonard Stejneger and Thomas Barbour. They updated their list four times in 1923, 1933, 1939 and 1943, but all omitted common names.

Although multiple alternative common names usually listed in regional or single-group publications, K. P. Schmidt in the 6th *Checklist of Amphibians and Reptiles of North America*, published by the American Society of Ichthyologists and Herpetologists (1953) may have been the first to attempt application of a single standardized common name for each taxon for the entire North American herpetofauna. In the same year the American Society of Herpetologists stuck a committee, chaired by Roger Conant, to revise common names, and produced a list published in *Copeia* 1956: 192–185 in time for use in Conant's pioneering field guide to eastern amphibians and reptiles for the Peterson Series, as part of an expansion of the series beyond the initial pioneering guides in birds. In 1978, a committee chaired by J. T. Collins produced a revised list for the Society for the Study of Amphibians and Reptiles (SSAR Herpetological Circular 1: 1-36) and Collins went on to produce revisions in 1982 (SSAR Herpetological Circular 12: 1-28), 1990 (SSAR Circular 19: 1-41), 1997 (SSAR Circular 25: 1-40).

The latest checklist, by a new committee, is a marked improvement over all previous editions as

for the first time changes in scientific names from the last edition are not only referenced to recent literature but conflicting opinions discussed. Now readers can readily track and evaluate decisions for themselves. Groups have been split among individuals or subcommittees: frogs: Frost; salamanders: Highton, Tilley (Chair), Wake; lizards: de Queiroz (Chair), Reeder, Sites; snakes: Boundry, Campbell, Crother (Chair), Taggert.

There is also a discussion of new rules applied in the formation of common names to provide more consistency, largely following the lead set by the American Ornithologists Union, which pioneered standardization of common names for birds long before the herpetologists attempted it. Numerous changes have been invoked. Just as we were getting finally accustomed to using Redbelly Snake, and similar contractions (Ringneck Snake, Redback Salamander, Hognose Snake, etc.) for compound names where a character was singular in an individual, we find the new list reverts to the traditional Redbellied Snake, etc., a form abandoned earlier as suggestive of an individual having multiple bellies. For a character with several occurrences in one individual, such as in Blue-spotted Salamander, the name is unchanged but the distinction between singular and plural states is now lost. Many other compounds have been changed to provide consistency. Thus the familiar Garter Snake becomes Gartersnake and Rat Snake becomes Ratsnake, presumably because the long used Rattlesnake has become the model. Other reversions invoked here are the undignified Stinkpot back again for *Sternotherus odoratus*. This had been changed to Common Musk Turtle in recent lists but the present compilers were apprehensive that "Common" might be misinterpreted to imply abundance rather than widespread!

Problems arise in compiling common names for both species and subspecies. Confusingly, sometimes completely unrelated names are still used for a species and a contained subspecies, such as *Notophthalmus viridescens* being designated the Eastern Newt, where as its nominate subspecies *Notophthalmus viridescens viridescens* is the Red-spotted Newt. It seems unfortunate that this committee has found it necessary to add suffixes to clarify (for those unfamiliar with amphibians and reptiles?) long recognized names such as Leatherback which becomes Leatherback Seaturtle. Fortunately atrocities like "Racer Snake" favoured by some Canadian conservationists apparently faced with considering reptiles for the first time, are not invoked. (Who would impose, for example, "Oriole Bird" to satisfy those unfamiliar with avian lifeforms?) Regrettably, some Canadian clarifications I proposed in 1984 (*Introduction to Canadian Amphibians and Reptiles*, National Museum of Canada), and followed for a time by some Canadian workers, such as Yellow-spotted Salamander for *Ambystoma maculatum*, to distinguish it from the Blue-spotted Salamander; Midland Chorus Frog for *Pseudacris triseriata* which is not a "western" species in Canada; or the distinguishing and informative names Tetraploid and Diploid Grey Treefrog for *Hyla versicolor* and *H. chrysoscelis*, continue to be rejected or ignored here as in the previous recent American lists. Although subspecies status for the Canadian Toad as *Bufo americanus hemiophrys* is still not accepted for this list, at least a reference to it as a possible philosophical treatment is included.

A positive innovation, instigated for the first time in a sanctioned list for amphibians and reptiles, is the capitalization of the first letter of each word in all common names of species and subspecies, to treat them as proper nouns, a practice borrowed from the American Ornithologists Union checklists for birds (and followed for 20 years in *The Canadian Field-Naturalist* for species names of all animals and plants).

This new checklist will be widely welcomed and followed. It is particularly valuable for consitancy of use by popular writers and conservation agencies (and editors) as it gives them an updated source of standard usage. However, it is a myth that common names are stable; every list sees some changes even of frequently used names. Unlike changes in scientific names which reflect new knowlege of relationships which necessitate change, those in common names seem to change on whim mainly with changes in committee membership. It is important especially for the non-herpetologist to note, however, that use of any list is not mandatory, it is simply the consensus opinion advanced by one expert committee at the time, and as such it is advisory only.

Scientifically, no list can do more than represent the state of the art at one point in time, and becomes outdated at the rate of new work that is constantly in progress. Since the appearance of this list, proposals have been published to remove the Wood Turtle from the genus *Clemmys* and resurrect either *Glyptemys* (Holman and Fritz, 2001, Zoologische Abhandlungen, Museum Tierkunde Dresden 51(20): 331-354) or *Calemys* (Feldman and Parham, 2002, Molecular Phylogenetics and Evolution 22(3): 388-398) from the synonymy (both first used in Agassiz, 1857, Contributions to the Natural History of the United States of America) for it and the extra-Canadian Muhlenberg's Turtle. Holeman and Fritz would apprear to have publication priority as first revisors. Both papers also suggest that the Pacific Pond Turtle should also be removed from *Clemmys* (leaving the latter monotypic with the Spotted Turtle, *Clemmys guttata*, as its sole species) and transferred with Blanding's Turtle into subgenera (placed in parenthesis) into the genus *Emys* as *Emys* (*Actinemys*) *marmorata* and *Emys* (*Emydoidea*)

blandingii. An alternative is to give both monotypic genus status and *Actinemys marmorata* and (as presently) *Emydoidea blandingii*.

Another change since the checklist is the separation of the Prairie Rattlesnake and North Pacific Rattlesnakes as *Crotalus viridis viridis* and *Crotalus oreganus oreganus* (Ashton and de Queiroz, 2001, Molecular Systematics and Evolution 21(2): 176–189).

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Pigeons and Doves: A Guide to the Pigeons and Doves of the World

By David Gibbs, Eustace Barnes, and John Cox. 2001. Yale University Press, New Haven and London. 615 pp., illus. U.S. $60.

This is another addition to the collection of books on bird families and groups that have been appearing over the last 15 or so years, perhaps triggered by the success of Harrison's 1983 volume on seabirds. All share an overall similarity in style, which will be familiar by now to most readers interested in this field, but vary widely in their approach to the details of their accounts. Harrison's book filled an important need for birders in providing an authoritative identification guide to a group of birds only poorly covered by other works. Some subsequent books in the genre have also emphasized identification, often with less success, while other authors have appeared to concentrate more on broader systematic and life history details.

The present volume deals only briefly [under three pages] with the characters of the family as a whole, and is no more than adequate in its coverage of identification. Its strength lies in the species' accounts, which provide a good summary of details relating to each species. Each occupies about a page and a half, plus a range map, and covers identification, voice, habits, habitat, and status and distribution, followed by a detailed description, with key measurements, and an outline of geographical variation. There is real merit in this approach, as the *Handbook of the Birds of the World*, Volume 4 [Del Hoyo et al. 1997], provides a most extensive and lavishly illustrated account of the family as a whole, but only relatively terse summaries for each species. By the same token, identification problems are well covered in field guides for most of the more popular birding destinations.

Looking at the species' accounts in more detail, I found that in general the detailed coverage seemed quite good, although noticeably weaker on North American topics. The range maps are erroneous for several species: for example, Mourning Doves are shown as non-breeding visitors in Canada and the northern US. The text is more accurate, but still implies that the Mourning Dove occurs no further east in Canada than southern Ontario. Similarly, neither text nor map shows White-winged Dove occurring in Florida. Curiously, the "Similar Species" entries for both the above birds discuss Eurasian Collared-Dove, but the text on the latter makes no mention of it occurring in North America at all! One of the problems facing birders here when identifying this species is separating it from the domesticated Ringed Turtle-Dove, usually referred to as *Streptopelia risoria*. This bird occurs quite frequently in the wild as an escapee, and there are well-established local populations of feral birds. Both the identification and systematics aspects of this subject have been well discussed in the literature, but all of this is wholly ignored in the current volume.

The colour plates follow the usual pattern, grouped at the beginning, with the images on the right and text on the facing page. The latter gives a line on distribution, and identification criteria for each image. Usually between 4 and 6 species appear on each plate, and as many as 19 separate images. Consequently some of the plates appear rather cluttered, but never confusingly so. The paintings are all by two of the authors, Barnes and Cox. Some are more convincing than others: I found the Australian bronzewings very disappointing, and the normally elegant Crested Pigeon looks downright ill. As a whole, the *Handbook of the Birds of the World* plates are more satisfying [Cox contributed to both], although I liked the small flight portraits in this work. There are no images showing the plumage variation in feral Rock Doves, although there is an entire plate devoted to the Passenger Pigeon.

Overall I found *Pigeons and Doves* rather disappointing. The errors in distribution information leave a sense of uncertainty about the text as a whole, identification details are often more thoroughly covered elsewhere, and the quality of the plates is uneven. The book also suffers from the problems of some others of this genre, as its intended audience seems rather ambiguous. If your interest is in the Columbidae, then this book could provide a useful compendium of information on the species in the family, but I doubt if the more general reader will find it worth the price.

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Handbook of Birds of the World Volume 7 Jacamars to Woodpeckers

Edited by Josep del Hoyo, Andrew Elliott and Jordi Sargatal. 2002. Lynx Edicions, Barcelona, Spain. 613 pp., illus. U.S. $185.

I thought the arrival of *Handbook of Birds of the World Volume 7* would mark a major milestone — the authors would be half way though their epic task. This is no longer true. After broad, worldwide consultation they have decided to publish 16 volumes to accommodate all the detailed material available. I have not seen a final publication date for this marathon task but it will likely be a dozen or more years away. In fact the elapsed time so far has been long enough for the Atitlan Grebe to go from "almost extinct "(Volume 1) to "extinct" (Volume 7). The change to 16 volumes, at about $200 a volume, will also add $800 to the total price. The authors have at least completed the non-passerines and to mark this point they have issued a plastic insert. This single sheet lists the families and genera in volumes 1 to 7 and gives volume and page numbers for each genus.

Handbook of Birds of the World Volume 7 opens with an essay on 132 extinct species. That is those species for which there is absolutely no hope of being found alive again. (Species for which there is hope, however small, are contained in the main text. This means Ivory-billed Woodpecker is kept as an extant species based on the recent Louisiana report.) Also discussed are the mystery birds — birds that have been described but for which there is no hard evidence of their existence. This is a fascinating account of birds well-known and obscure that come from a shadowy world of science blended with half truths, mistakes and over zealousness. It provides a fine background to extinction and sets the stage for understanding the fragility of some currently endangered species. I was particularly interested in the author's comments on the Tachira Emerald (*Polyerata distans*). First, I found the index was in error by a page. The authors referred to this bird as a probable hybrid (presumably Glittering-throated Emerald [*Polyerata fimbriata*] × White-chinned Sapphire [*Hylocharis cyanis*]) but gave little discussion except to suggest it was probably not extinct.

This volume covers jacamars to woodpeckers, in all just over 400 species. With all of the species covered it is easy to place them in their family. All the jacamars, for example, are similar and typically are chestnut and emerald. Likewise the puffbirds can be characterized as brown, black, and dumpy. The woodpeckers, which constitute over 45% of this volume and account for 55% of the species, fall into characteristic groups. All are immediately identifiable as a woodpecker, and then it is simple to clump them into distinctive groups. For example, the flickers are a very obvious coherent unit. It is not until you look at the barbets and the toucans that you see some wild diversity. Even here it is not the body shape but the colour that varies. The multi-coloured toucans and barbets are South American. The more uniform brown species of barbets are African and the green ones are Asian. I did note that the Gilded Barbet, *Capito auratus*, (a very nice depiction in the plates) is lumped as the Black-spotted Barbet, *Capito niger auratus*. Other recent publications have given this bird full species status.

The section covering each family begins with a summary box which gives basic information on classification and range. It shows silhouettes of the species within the family compared to that of a human. This summary provides a quick visual introduction to the main text.

This text for the introduction of the family is reasoned, current, and instructive, and it provides a solid basis for understanding the family while providing a point of reference for future studies. The content of the individual species descriptions is informative, providing a satisfactory level of essential information while avoiding cloying detail. The book ends with about 4000 bibliographical references.

It is interesting to note that DNA studies are having a significant impact on our ideas about species. In this volume the authors split the European and American Three-toed Woodpeckers based on DNA results. They further suggest that other disjunct populations may also be separate species.

The artwork lives up to the typical, high HBW standard. I scanned through looking for errors and found none, just a few minor discrepancies in depth of colour. Most notably the wings on the Cream-coloured Woodpecker are not brown enough. This is actually confirmed by a photograph of this species earlier in the text. Additionally, I noted there are more representations of females than in earlier editions. The over 300 colour photographs run from good to great. The photographs are not merely an extension of the plates. Rather they are a complement to the text and plates. They highlight aspects of the bird's biology and behaviour, coupled with a glimpse of its habitat, leaving the artwork to provide a means of identification

The range maps are clear and show the currently accepted distributions. Whether they are accurate is a little more difficult to judge. Many of the species live in remote areas that are not well known. The map size 5 × 3½ cm is quite small. When compared to *Birds of the Western Palearctic*[1] or *Birds of Canada*[2] this map size is a little difficult to interpret. For example, it is not easy to see the difference in range between the Emerald Toucanet and the Chestnut-rumped Toucanet which, in reality, are separated by the Andes mountain range.

So this great contribution to ornithological literature steam rollers on slowly transforming itself into *the* bible of birdwatching. It is hard to believe that I will be in my seventies before the last volume is produced and the creators will then have to consider revising Volume 1.

References

[1]The Birds of the Western Palearctic, Chief Editor: the late Stanley Cramp, Editor of Vols. I-IV: K. E. L. Simmons, and Editor of Vols. VII-IX: C. M. Perrins, 1994. Oxford University Press, England.

[2]The Birds of Canada, Bulletin 203 (Biological Series 73), W. Earl. Godfrey, 1966. National Museum of Canada, Ottawa, Ontario. Revised Edition 1986.

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The Marbled Murrelets of the Caren Range and Middlepoint Bight

By P.H. Jones. 2001. A Western Canada Wilderness Committee Research Report. ISBN 1-895123-13-5. 150 pp. $34.95.

"British Columbia is endowed with one of the most diverse and probably the richest natural heritage in Canada and yet so little is known of this vast resource". This book is not strictly a scientific one, but surprisingly, the first of its kind. It provides the reader with an alternative and widely shared view on the Marbled Murrelet issue in southern British Columbia. It is about the classical conservation battle for a habitat and a species of world importance: the Marbled Murrelet (MaMu), *Brachyramphus marmoratus*, and its nesting habitat, the coastal Old-Growth Forest.

The author states "I was alarmed at what was happening on the Caren and elsewhere in the province. My respect for the profession of forestry had clearly suffered a huge shock". The book is for MaMu-holics written by a Murrelet-phil. But it is also suggested reading for any naturalist and wildlife ecologist in the Pacific Northwest and beyond. Readers learn from a first-hand account on "how to find a Marbled Murrelet nest", as well as about many aspects of the fascinating biology of this bird, including all the politics around it.

Certainly, the finding of the first active Marbled Murrelet nest in Canada on 12 August 1993 makes for a central theme of this book. The discovery presented a major effort over many years, based on a tremendous amount of amateur field-work and vision; eventually it turned into a success. However, the events that led to this historical finding deserve some attention. For instance, it is not clear why the people who first located the nest were not authors in the forthcoming publication. The overall motivation and funding situation for "The Caren" remains somewhat unclear as well.

Many fascinating details about this bird, its habitat (including the sea) and its inhabitants can be learned from this publication, too. For instance, the Caren Range claims the oldest tree in Canada with a confirmed age of over 1700 years; the discovery of this finding is worth a read in itself. Well-rounded, the text even presents "MaMu-history" and native aspects. And certainly, a fair bit of lifestyle in coastal British Columbia is described. The Marbled Murrelet is not only a species difficult to study, but also to draw. The author includes tasteful and nice black-and-white illustrations of this bird.

The statement of the author that Marbled Murrelets are unlikely migratory can be confirmed (wintering birds are found consistently along the British Columbia coast). Although not well liked by Canadian governments, this fact has major conservation implications because according to the Bird Migratory Act 1917 the federal government can only support migratory species; this bird not being migratory would drive the responsiblity in the hands of the provincial government. The author states on this subject "*...Provincial authorities in British Columbia have done virtually nothing to protect marbled murrelets and to set them on a path of recovery*". It is worthwhile to mention that besides facilitation, the federal goverment has also not provided much guidance in the last years on this matter.

Several interesting biological features about Marbled Murrelets are reported in this book: locations and timing of moult. Other jewels in this book might be the raw data on nest visits, and pair-bonding described for October. The described mating observations, the murrelet foraging process, and transformations of summer and winter plumages in September are also precious. The claim that Marbled Murrelets could be identified individually, and that males could be distinguished from females in the field, deserves more proof; at least this has never been reported anywhere else in the world. Another concern is that Mew Gulls don't depend on the Old-Growth Forest, and re-use of Marbled Murrelet nests is seen as a rather rare event, so far. I would doubt, too, that this bird is colonial, as hinted in the text. Unfortunately, the statements about the Simon Fraser University are disagreeable and need correction (e.g., a cliffnest was indeed found by this group, and over 150 nests were located in the last four years

with radio-telemetry from helicopter). For these subjects, the reader is suggested to contact the researchers from the Centre for Wildlife Ecology directly, or check their website (URL: http://www.sfu.ca/biology/wildberg/species/mamu.html). Besides the claim of the author and the obvious loss of Old-Growth Forests, there are still no statistical indications that the populations in British Columbia overall have in fact declined — a topic of major controversy. A less disputed point is made in this book that the traditional hype about the nesting habitat is not really reflecting the overall life-needs of the Marbled Murrelet; the marine aspects of this bird are even less studied, nor do any (!) Marine Protected Areas exist along the unique coastline of western Canada (Middlepoint Bight as a feeding area might present one candidate).

The issue of the effect corporate funding would have on science, and on Marbled Murrelet research in particular, is still open for discussion, but is heavily argued, here. Since controversial topics are reported on, names like Randy Stoltman, Mike Harcourt, and Glen Clarke are not missing in this book. The footprints left by prominent Marbled Murrelet researchers in British Columbia like Spencer Sealy, Harry Carter, Jean-Pierre Savard, Gary Kaiser, and others are found throughout.

"We made our point, too, with the Forest Service that it was they who were forcing the companies to get out there and log the Caren, even when there was a government process in place to protect areas like the Caren!". Obviously, the management of the forests in British Columbia gets much debated in this book, as elsewhere. "We cannot have a Ministry of Environment which is subservient to a Ministry of Forestry as has been the case in the past". The term "overcutting" is mentioned many times by the author. It is not clear how this can occur in a country that claims to do "sustainable forestry"; apparently without any relevant and consistent ground-based inventory of Old-Growth Forests! Jobs matter in British Columbia, but due to odd and failed management, the international forest industry – to name Japan, USA, and even Norway – has become the main drivers of the agenda of forests in coastal B.C.

The author refers often to the "Marbled Murrelet Recovery Team", which is supposed to do something good for the Murrelets. The Protected Areas Strategy (PSA) and the BC Forest Practices Act might be one approach. However, other solutions exist, and as this book clearly indicates, nests are not found in low elevation but rather at higher elevations (>400 m) and with steeper slopes. The least one could say about all this is that Marbled Murrelets are very robust in their nesting habitat, which covers apparently a wide range of landscape and tree characteristics. This puts doubt on the Marbeled Murrelet as an indicator species, since it "indicates" so many habitat features (way beyond the low elevation forests, a traditionally claimed prime nesting habitat for this bird). Biases in Marbled Murrelet research and conservation are introduced by investigation approaches with a poor research design, by the management term "forest stand" (basically impossible to define objectively in the field and from maps), by using the term Old-Growth Forest (over 12 definitions exist), and by the current counting scheme for Murrelets in the forest (titled "Occupied Detection" surveys). As the author confirms, the Canadian counting protocols used for Occupied Detections and at-sea surveys differ markedly from the ones used in the United States.

The author is certainly not an "ecoterrorist"; instead, he is a devoted naturalist and deeply concerned about his "backyard", the Caren Range and Middlepoint Bight. His book provides an emotional and passionate narrative. It presents a textbook-example to concerned citizens and naturalists about his battle with local experts, the local District Forester, and governments to convince and to achieve his case; these are experiences one makes when interacting in "territories" of the established and so-called local experts. This recommended book shows how he succeeded.

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Hummingbirds of North America: The Photographic Guide

By Steve N. G. Howell. 2002. AP Natural World. Academic Press, San Diego. 222 pp,. illus. U.S. $24.95.

Photographic bird guides have a rather chequered history. They seem like a good idea, but in practice they have all too often proved to be less than ideal, with poor poses, ambiguous colours, and a lack of uniformity all combining to reduce their utility. So I approached such a guide to hummingbirds with considerable skepticism — after all, hummingbird colours can be difficult to determine at the best of times, and their behaviour doesn't help much.

But Steve Howell has surmounted all the usual problems. This is the ideal photographic guide, with a multitude of carefully selected poses, detailed information in the captions, and meticulous attention to the appearance of each image.

It has a text to match. The highlights of the 34-page introduction are a section entitled "taxonomy and identification framework", which includes a review of the characters of the North American genera, and a very detailed and comprehensive outline of field identification. The latter — like the rest of the book — has large and carefully annotated illustrations which complement the text very well. The author's own words summarize the challenge this barrage of information poses to the reader. He says: "While the foregoing may seem an almost overwhelming amount to digest, there is no hurry". This section does indeed put a whole new perspective on hummingbird identification, and presents a whole new set of challenges to those of us in the east. So I greatly appreciated his comment. It neatly sums up his practical, down-to-earth approach to the entire book.

The heart of the guide is a detailed account of the identification of the 22 species of hummingbird that either breed or have occurred in North America north of Mexico, plus Cuban Emerald and Bumblebee Hummingbird, for which reliable sight records or specimens exist. Treatments range from some 12 pages each [including four devoted to 11 or 12 photographs] for widespread and tricky species such as Ruby-throated and Black-chinned, to four pages for easier and less common species. In fact, the coverage of Ruby-throated and its "look-alikes" also benefits from a five-page discussion on the "small gorgeted hummingbirds". All the species are dealt with genus by genus, and have a short general statement on the characters of the genus as a whole at the beginning of each section. The book concludes with a glossary, a list of references, and a short index.

This is an excellent, carefully conceived, well-written and practical guide, obviously by someone who has an intimate familiarity with his subject. I found the occasional mistake, and the approach to reference citations was a bit confusing at first, but overall it is hard to find fault with this book. It's yet another in the sequence of superb guides that have been published in the last few years, and it's one that will prove invaluable to easterners like myself who suddenly find themselves faced with an array of these enchanting yet pernickety little creatures on a trip out west. I think I'll go back to Arizona and try it.

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State and Provincial Amphibian and Reptile Publications for the United States and Canada

By John J. Moriarty and Aaron M. Bauer. 2000. Society for the Study of Amphibians and Reptiles, Herpetological Circular Number 28. 52 pp. [Available from SSAR Publications Secretary, Robert D. Aldridge, Department of Biology, Saint Louis University, St. Louis, Missouri 63103 USA; e-mail: ssar@slu.edu]. U.S.$8.00.

This bibliography compiles North American lists and guides for 51 states of the U.S. and 10 provinces and three territories (plus a general category for the Canadian Maritimes). The earliest entries are Storer 1840 for Massachusetts and DeKay 1842 for New York. In all, 835 entries are listed, or 881 if multiple entries under several categories are individually counted. In the United States Florida leads with 46 citations; in Canada, British Columbia has the most, 10. The scope is limited to publications dealing with a single state or a significant portion of one. Publications dealing with more than three states or provinces have been excluded, except for the historic regional units of New England (Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, and Vermont) and the Maritimes (here defined in error as New Brunswick, Newfoundland, Nova Scotia, and Prince Edward Island - in proper eastern Canadian usage the four together are called the "Atlantic provinces" and "Maritimes" is restricted to references to the three that joined Canada in the 1800s, excluding Newfoundland which did not join until 1949).

This publication serves as a handy reference for entrance to provincial and state literature and should have wide circulation and use. Of interest is that seven of the Canadian entries are to papers in *The Canadian Field-Naturalist* and its predecessor *The Ottawa Naturalist.* A major historic omission for Ontario is J. H. Garnier. 1881. List of Reptilia of Ontario. *Canadian Sportsman and Naturalist* (Montreal) 1(5):37-39 and, for Quebec, Leon Provancher 1874. Faune Canadien. Les reptiles. *Le Naturaliste canadien* 6: 273-278; 289-298; 321-330; 353-370. and 1875. *Faune Canadien. Les reptiles. Le Naturaliste canadien* 7:10-20;42-46;65-73.

Its usefulness could have be enhanced considerably by including a section for the major regional guides to larger units in North America both for amphibians and reptiles, and for the groups within them.

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Salamanders of the United States and Canada

By James W. Petranka. 1998. Smithsonian Institution Press, Washington and London. xvi + 587 pp., illus. + plates. U.S. $60.

James Petranka, Biology Department of the University of North Carolina, has 20 years in the field as evidenced by 22 entries as senior author, the first in 1979, in the bibliography of this book. Among them are fieldwork oriented papers on winter effects on woodland salamander (*Plethodon*) populations in Kentucky, effects of timber harvesting on southern Appalachian salamanders, and ecology of the Small-mouthed *Ambystoma texanum* and Marbled, *A. opacum,* salamanders. For this book he has set himself a daunting task. The last comprehensive compilation of North American salamanders was by Sherman C. Bishop (1943) in the Comstock series of classic "handbooks" pioneered by A. H. and A. A. Wright (who wrote the frog and snake volumes) from Cornell University. A new synthesis is especially long overdue considering the importance of the area covered. North America, with 9 families and 24 genera, has the greatest diversity of salamanders in the world. As well, from 1943 to 1997 more than 1500 refereed research papers on systematics, ecology and natural history of North American salamanders have appeared and more than 30 new species have been described.

Setting out his approach in his Preface, Petranka first faces the critical questions of taxonomy (naming units) and systematics (arranging these units in relation to one another), both highly contentious topics among current salamander specialists who have varying criteria and philosophies (e.g., biological, evolutionary, and phylogenetic species definitions) guiding them. As a result, the number of species recognized can vary from fewer than 110 to more than 150. Petranka recognizes 127, reflecting a moderately conservative approach.

The Preface is followed by an Introduction which gives brief overviews of content, diversity, ecological roles, life history, and general natural history. A section on Salamander Identification and Plan of the Book is next, then one on Conservation Biology of Amphibians, and Key to Adult Salamanders and Key to Larval Salamanders of the United States and Canada. The book concludes with a Glossary of 51 terms and a Literature Cited of about 2100 references, Collection Localities (to county generally) and Photographic Credits for Color Plates, and a five-page index to genera and species.

The bulk of the book (pages 35-492) is the family and species accounts. The former cover characterization, fossil history, and major systematic treatments. The latter give scientific and common name and include sections on Identification, Systematics and Geographic Variation, Distribution and Adult Habitat, Breeding and Courtship, Reproductive Strategy, Aquatic Ecology (where applicable), Terrestrial Ecology (where applicable), Predators and Defense, Community Ecology, Conservation Biology, and (sometimes) Comments. The text of these sections is rich in references and emphasizes comparative geographic coverage of ecology, behaviour and life history. Within the species accounts there are one-column black-and-white photographs of adults (occasionally several views), and often of larvae, eggs, and spermatophores. There is a page-width continental map of the United States showing distribution as grey blocks for monotypic species and in varied hatching and marbling for subspecies of polytypic forms. For species which range north into Canada most provinces are added but the state of Alaska (*Taricha granulosa*) and the Labrador portion of Newfoundland (*Eurycea bislineata, Ambystoma laterale*) appear only where there are species ranging there. Finally, inserted in the center of the book are 172 colour photographs of adults and larvae, with subspecies included for a few polytypic forms (*Ambystoma tigrinum, Notophthalmus viridescens, Eurycea longicauda, Gyrinophilus porphyriticus, Pseudotriton ruber, Taricha granulosa, Siren intermedia*).

This thorough and comprehensive book is a worthy successor to the pioneering text of Sherman Bishop nearly 60 years ago. It will be on the essential reference shelf of every professional herpetologist, and consulted for detailed information and references by a legion of field naturalists and conservation environmentalists of every hue.

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Patterns of Distribution of Amphibians: A Global Perspective

Edited by William E. Duellman. 1999. The John Hopkins University Press, Baltimore and London. viii + 633 pp., illus. U.S. $69.95

The phenomenal growth of research on amphibians and reptiles in the last half of the 20th century, including the description of a multitude of new species to bring the world total to over 4700, ever more precise data on ranges, and fine-tuning of relationships partly though the ever expanding use of DNA analysis, has made possible the new synthesis attempted here of the mosaic of individual ranges throughout the world. The first chapter is an overview, "Global Distribution of Amphibians: Patterns, Conservation, and Future Challenges" (William E. Duellman). This is followed by nine individually authored chapters on amphibian distribution divided geographically: "Nearctic Region of North America" (W. E. Duellman and Samuel S. Sweet) "Middle America" (Jonathan A. Campbell), "West Indies" (S. Blair Hedges), "South America" (W. E. Duellman), "North Africa", "Europe", "Western Asia", and "former Soviet Union" (Leo Borkin), "temperate Eastern Asia" (ZhaoEr-Mi), "Southern Asia and adjacent islands" (Robert F. Inger), "Sub-Saharan Africa", "Madagascar, and Seychelles" (J. C. Poynton), and "Australo-Papuan region" (Michael J. Tyler). Some of the contents were originally prepared for presentation in a symposium at the Second World Congress of Herpetology in Adelaide, Australia, in December 1993 but new data have considerably augmented the presentations.

Duellman's initial overview chapter is comprehensively illustrated with graphs and tables of continental comparisons and contrasts in number of families, genera and species, the rate of description of new species, as well as the geographic occurrence of endemism, all of which will be useful not just to every herpetologist but also to the non-herpetologist for contrast with their own groups, and to the general naturalist for perspective of where this group fits into the natural world. The discussions of conservation and the declines and the need for more research cover much that is familiar, but which can never be restated too often.

Although the southern areas of the world have the major share of extant species (South America leading, with 2465), and much of the diversity of families and genera, it is the northern continents that will be of immediate interest to Canadian herpetologists, ecologists, and naturalists, North America with 241 species, and Eurasia with 192.

The Nearctic Region as defined by Bill Duellman and Sam Sweet (pages 11-110), has 90 anurans (frogs, toads, and kin) and 151 salamanders. Maps and discussions of a selection of generalized environmental divisions and specific variables are presented. Major physiographic provinces are defined as (from west to east) North American Cordillera (Pacific Ranges, Intermontane Plateaus, Rocky Mountain System), Interior Plains (Great Plains and Interior Lowlands), Laurentian Shield, and Appalachian Highlands. The majority of species occur outside the maximum former extent of Wisconsin glaciation and therefore much of the discussion is of patterns south of it. There are generalised maps of limits for the 15 most northerly species but the boundaries shown are unfortunately inaccurate in places. Surprising is the statement (page 83) that "there are no clear correlations of distributional limits with temperatures". The pioneering herpetofaunal zones defined for eastern Canada by J. S. Bleakney in 1958 (National Museum of Canada Bulletin 155) are not discussed nor is his paper even cited. My 1984 *Introduction to Canadian Amphibians and Reptiles* is, but the only other Canadian references included are Anthony Russell and Aaron Bauer's guide to Alberta species, two publications by David Green, his students and colleagues, and one in which the master of freeze tolerance, Ken Storey, participated.

The northern Palaearctic with 69 salamanders and 106 anurans is covered by Leo Borkin (pages 329-420) who effectively presents data debunking the concept of a Holarctic unit for amphibians. The latter has sometimes been invoked by past workers because of well-established faunal similarities at a species or subspecies level in some other terrestrial vertebrate groups (birds and mammals) and some invertebrate and plant groups. In contrast, amphibians (like reptiles) share no species or sister species between Old and New worlds. Only four genera of amphibians (one salamander (*Hydromantes*) and one each of frogs (*Rana*), treefrogs (*Hyla*), and toads (*Bufo*) are represented in both, and none of three frog genera are exclusive to the northern regions. Even on the family level, of the 5 salamander and 8 anuran ones in the Palaearctic and 9 and 8 in the Nearctic, only four of 10 salamander and five of 11 anuran (frogs and kin) that occur in the two regions combined are common to both.

The book is an instant classic reference, rich in data and comparison and contrast, a tribute to the industry of all its authors, but especially of its editor who has been a ever-growing force in amphibian systematics and zoogeography over four decades.

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The Amphibians of the Former Soviet Union

By S. L. Kuzmin. 1999. Pensoft, Sofia, Bulgaria, and Moscow, Russia. vi + 538 pp., illus. U.S. $98 + U.S. $12 shipping.

For Canadians, this fine book gives a view of essentially a faunistic "alternate universe" to what they are familiar with – an amphibian assemblage evolving independently from that of North America since the Miocene yet coping with the same northern environmental problems. Previous overviews have been available in English translation of Russian classics textbooks; this is a new text written in English.

The Preface comments on past major texts for the area, the former USSR retained here as the area covered with the terse comment that "The Soviet Union is no longer respected as a single political entity because of its dissolution and the creation of the Commonwealth of Independent States (CIS) and several Baltic Republics". The information presented is selected from the author's database of 4000 bibliographic sources [a vast majority not available in English] and 7500 localities; still in progress, explanations with diagrammatic illustrations of standard measurements used for various groups and life stages, and use of a compilation on ecology for each species. Chapters 1-5 (the first 99 pages) cover History, Faunistics and geography, Ecology, Anthropogenic pressure and conservation, and Keys for species identification. The book ends with a 66-page bibliography, 26 pages of detailed spot distribution maps, 32 pages of habitat and species colour photographs, a 4-page glossary, 5-page systematic index of amphibians, 4-page Subject Index, and finally a 3-page list of species and subspecies of the area covered.

The bulk of the book, 300 pages, is Chapter 6, "Species accounts". Genera are briefly characterized here as well, before each group of species they contain. Each species account is headed by English and Latin name, synonymy, and Russian, German and French names. The sections for most include Taxonomic notes, Description (Morphology and Karyology), Distribution, Subspecific differentiation, and Variability, Ecology (Habitats and abundance, Thermobiology and Activity cycles, Reproduction, Development, Feeding, Natural enemies, parasites and diseases), Influence of anthropogenic factors, Status and conservation, and References.

In all, 40 species (27 frogs [28 if the "klepton" *Rana esculenta* is included] and 13 salamanders) are represented compared to 44 (24 frogs and 20 salamanders) in Canada. At the family level the Pelobatidae is represented by the genus *Pelobates* (2 species) instead of the North American endemics *Scaphiopus* and *Spea*) whereas Bufonidae, Hylidae and Ranidae have genera in common, *Bufo* (7 species), *Hyla* (3), *Rana* (11). The toads are in two species complexes: the Common Toads, *Bufo bufo* (3 species) and the Green Toads *Bufo viridis* (4). Both groups lack cranial crests in common with the North American Western Toad, *Bufo boreas*. All the hylids are the European Treefrog, *Hyla arborea*, complex, and look superficially similar to the North American Pacific Treefrog, *Hyla regilla* [now included in *Pseudacris* by most authors]. In the ranids, the brown frog group has some species that resemble the North American Wood Frogs, *Rana sylvatica*, in having dark snout "masks" and some having dorsal stripes. But many have red ventral colouration, not seen in Wood Frogs but present in some western North American dorsally brown coloured frogs, *R. pretiosa, R. aurora*. Whereas American Wood Frogs hibernate on land as far as is known, the Eurasian brown frogs hibernate often in the water with some species hibernating sometimes on land as well. The five species in the green frog group are primarily pond frogs somewhat like the North American *Rana clamitans* group in ecology, hibernating most often in the water and with tadpoles that sometimes overwinter. But their patterns often include spotting that resembles North American *Rana pipiens,* and sometimes a middorsal stipe, a character found predominantly only on the Wood Frog in North America. Included in the Eurasian green frog group is a complex of two species, the Marsh Frog *R. ridibunda* and Pool Frog, *R. lessonae,* and a hybrid of the two, the Edible Frog, *R. esculenta,* a "klepton" which can cross with either to produce both frogs with the genetic constitution of the hybrid and also frogs that are genetically identical to one or the other parental species depending on which is involved in a particular cross. Families which do not occur in North America are Discoglossidae (*Bombina,* 3 species) and Pelodytidae (1 species). Of the salamanders, only one family (Salamandridae, the newts) is shared but none of the three genera represented occur in North America (*Salamandra* (1 species), *Mertensiella* (1), and *Triturus* (7) [although the species in both endemic North American genera, *Notophthalmus* and *Taricha*, were at one time included in the latter genus]. The Hynobiidae ecologically partly replaces the North American endemic families Ambystomatidae and Plethodontidae with species markedly similar in form and colouration to some of these represented by the genera (one species in each) *Hynobius, Salamandrella, Ranodon,* and *Onychodactylus*.

The book is packed with fascinating comments and rich in data. The historical lore recounted includes that of the ancient aboriginal people of the Kamchatka Peninsula, the Itelmens, who suspected that Siberian Newts, *Salamandrella keyserlingii* were spies of Gaech, lord of the underground. The Itelmens therefore killed newts in the belief that if

the animal saw a man and was allowed to return to its master and report him that man would die (page 8). Another ancient belief recounted is that mermaids by their sad songs decoyed people into deadly swamps, which may have been based on the evening calls of Fire-bellied Toads, *Bombina* (page 9). The ecological sections of the species accounts include such data as that on the Moor Frog, *Rana arvalis,* which in one 6 km^2 area of mixed forest in West Siberia, has a population estimated at approximately 90 000 individuals (biomass 190-200 kg), which will consume 55-60 kg of invertebrates per summer day (page 322). In contrast to North America, where none of our salamanders are known to be freeze-tolerant and all fall far short in ranges of the most northerly ranging frogs, *Salamandrella keyserlingii* is reported to survive temperatures of -35 to -40 Centigrade, and ranges farther north than any other Russian amphibian. It is the only amphibian to occur in the severe climate of the Kamchatka Peninsula. As in North America, only one frog ranges northward over the Arctic circle. In Canada, the species is the American Wood Frog, *Rana sylvatica,* in Russia the Siberian Wood Frog, *Rana amurensus,* although the Moor Frog, *Rana arvalis,* comes close in the eastern portion of the country.

If the book has a fault, it is that the text, although having a list of citations at the end of each species account, does not cite individual papers after statements in the text, thus not allowing the source of particular data of interest to be quickly traced in a literature that will be so unfamiliar to most North Americans.

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The Atlas of the Amphibians and Reptiles of Vermont December, 2001

By James S. Andrews and 1400 dedicated volunteers and organizations. 2002. [Privately printed] James S. Andrews, Middlebury, Vermont. 90 pp. Available from Cindy Brown, Biology Department, Middlebury College, Middlebury, Vermont 05753. U.S. $15 (plus 0.75 Vermont sales tax).

On the two occasions in the past year when Jim Andrews has given a presentation at a meeting we have both attended, he invariably has begun by illustrating the former dependence on non-Vermonters for information on amphibian and reptile distribution in the state by singling out my critical review of a book on New England amphibians and reptiles in 1984 (*Canadian Field-Naturalist* 98(3): 406-407). To illustrate the lack of a comprehensive check of museum collections by the authors I had appended a note by F. W. Schueler his (until then) unreported and therefore overlooked specimens of Chorus Frogs, *Pseudacris triseriata*, the first record of the species for New England, collected in 1975 in northern Vermont and deposited in the Canadian Museum of Nature.

Actually, a distributional database for the state had already begun by the time my comments were published, thanks to The Nature Conservancy's Heritage Program whose methodology was introduced throughout New England in 1983. An advisory Endangered Species Subcommittee for Reptiles and Amphibians was formed for Vermont with Mark DesMeules as chair. This led to the compilation of a *Preliminary Atlas of the Reptiles and Amphibians of Vermont* published in 1995. Included were records from museums, publications, and a host of field observers. The project has continued and since 1995 over 1400 individuals have contributed 12,000 new records, for a database total of over 30,000 records. Jim Andrews (who has contributed over 10,000 records himself) has coordinated the atlas project since 1994 and is the current chair of the Vermont Reptile and Amphibian Scientific Advisory Group. No longer was Vermont largely dependant on occasional travellers for information on rarities.

The maps presented cover 40 species considered native to the state: 10 salamanders, 11 frogs, 7 turtles, 1 lizard, and 11 snakes. For the Blue-spotted Salamander complex multiple maps are included to separate the complex as a whole, each of the two diploid species, and each of the polyploid hybrid combinations associated with each of these. In addition, three salamanders and two turtles are listed for which specimens exist which are thought to be the result of mislabelling or released captives (of these only the Allegheny Mountain Dusky Salamander is mapped). The maps indicate if a species is present in any of approximately 245 geopolitical "town" divisions (key to these is given on page 15) by hatching for historic records (prior to 1976) and shading for current records (1976 through 2000). Most important, and an innovation Canadian atlassing projects might well consider, is a distinction (in this case a dot) added for the most valid records, those which are documented by a photograph, tape recording (for frog calls), or specimen. Inner front and inner and outer back covers present colour-coded maps of numbers of new species reported in each township since the 1995 edition, total species reported for each

township as of 1 January 2001, and degree to which each town has been surveyed to show the areas most in need of additional survey.

The simplified mapping system works well for encouraging volunteers to "fill in the blanks" but it is frustrating for any but the broadest-scale zoogeographers and ecologists. Those needing precise plotting of localities for finer scale comparison with vegetation or geographic variables will not find it here. The centre-of-a-block method is arguably less work. It also is conservation-friendly in as much as exact localities are not pin-pointed and thus avoid (or at least make more difficult) its use for the exploitation of rare or commercially valuable species. However, at the same time it obscures critical habitat locations from possible developers (or opposers of development) who might not destroy populations of rarer species if they could readily check for their presence. Either could, of course, take the additional time necessary to access the original data files to check if a rare species indicated for a town might be present in the exact locality of their concern. Hopefully, responsible people would.

The concluding text has tables of the number of records for each species and a plea for continuing help as there is so much still to learn. A section on documenting records is the clearest explanation and justification I have seen for why and how to do this with special care. In addition, there are tips on searching and handling, permits and licences required and ideas for educators. There is an eight-page, four-column list of contributors of up to 19 records, followed by a page listing those contributing 20 to 99 and more than 100. A list of field employees and drift fence volunteers includes 72 people and an Audubon Take PART Program an additional 36; organizations that contributed records totalled 36, and museums 13. There is a five-page bibliography, a list of eight advisors, a page of useful publications, tapes, and websites, three pages of additional reading on amphibians and reptiles, and a two-page reporting form for observations.

This and other atlassing projects in neighbouring states and provinces are not just invaluable for the documentation in itself, but also in their promotion of future effort and usefulness as a basis for conservation initiatives. Because they specifically acknowledge each individual contribution they promote public support and encourage continued involvement. The present work based on presence/absence data will lead eventually to the next, and even more difficult step in atlassing, the mapping of annual relative abundance geographically. To do this we yet need to learn how to accurately measure amphibian and reptile populations, a task both challenging and illusive.

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Snake

By Chris Mattison. 1999. Firefly Books, Willowdale, Ontario. 192 pp., illus. $39.95

This large format (28.7 × 23.7 cm), "coffee table" style book has spectacularly crisp colour photographs, and an encyclopedic text packed with capsule facts. It begins with a single-page introduction which promotes an interest in, and appreciation of, snakes.

Following are three major divisions. The first, the Essential Snake, covers evolution, environment, size and shape, scales, anatomy and movement, skull and teeth, sense organs, hunting and feeding, venomous snakes, passive defense, active defense, reproduction, conservation, and classification of snakes, most topics covering two facing pages and all illustrated by colour photographs and diagrams.

The second, Snake Gallery, covers a selection of 61 primary species each also mostly on a two-page spread, with a center portrait of the featured species sprawled across both pages. Fitted around it are the species name, a summary of its main characteristics, a diagram of relative size giving average and record lengths, additional pictures showing particular morphological or behavioral characteristics, a "fact file" giving Latin name, family, habitat, breeding, feeding, and distribution, the latter with a tiny globe with the geographic range in red, and an inset box with a topic supplemental to the main text, either conservation issues or other related species.

The third, Snake Directory, is an unillustrated four-columns-to-a-page listing. Each family is given with its characteristics followed by included genera in alphabetical order. Each genus has the number of species, size, distribution, habitat, food, reproduction, notes. Species are listed with scientific and English names (if one of the latter is in common use) and a dot if featured in the earlier Snake Gallery section. The book concludes with a 52-entry Glossary, Index, and Acknowledgments.

As a visual of major topics in snake biology and representative world snake diversity along with a convenient easy-to-scan summary of conservative classification and species of world snakes the book is a success. It will be useful on any bookshelf for quick reference to the diversity of snakes. Unfortunately, it

lacks any bibliography, so the reader can not follow up topics of particular interest to sources where they are discussed in greater detail. For this, reference to more detailed and academic snake texts will be needed.

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A Field Guide to the Amphibians and Reptiles of the Maya World: The Lowlands of Mexico, Northern Guatemala, and Belize

By Julian C. Lee. 2000. Comstock Publishing Associates, Cornell University Press, Ithaca, New York. 402 pp., illus. U.S. $35.00

Amphibians and reptiles do not generate the constant degree of general field-naturalists' attention, travel, and consequent book demand that birdwatching does and therefore the appearance of a field guide to them for an area south of North America and Europe is an event. *A Field Guide to the Amphibians and Reptiles of the Maya World* is such a book. It is of general interest as amphibians and reptiles (in contrast to birds) are non-migratory, except for marine turtles, and therefore only the latter may actually share individuals with the northern hemisphere. Other groups have long evolved independently and the southern herpetofaunas have not been periodically eradicated through the Pleistocene by repeated glaciations.

Most field guide coverage is defined by continents or "artificially" (from a biological point of view) by political units: countries, states, or provinces. In this guide to the Mayan world, the choice taken breaks from this tradition by selecting a geographical block lying north and northeast of the 600-metre contour in the highlands Alta Verapaz, Guatemala, and the Meseta Central of Chiapas, Mexico. The area includes the southern Mexican states of Yucatan, Quinta Roo, Campeche, and portions of Tabasco and Chiapas, as well as the countries of Belize and Guatemala and portions of Honduras. The lowlands thus focused on were the home of the indigenous people of the Yucatan peninsula, the Maya, hence the book's title.

The guide begins with the mandatory Preface and Acknowledgments. These are followed with an Introduction explaining the area covered, how to use this book, conservation, organization of the species accounts. An Environment section outlines physiogeography, climate, and vegetation; a habitats one describes coastal, agricultural, freshwater, forest, and savanna. A discussion of the composition of the herpetofauna precedes the species accounts which are the bulk of the text, 238 pages. The book concludes with a Glossary (11 pages), Literature cited (7) and Index (8).

Species-by-species coverage includes paragraphs on identification, similar species, distribution, natural history, and key reference citations for each account. It is richly illustrated. There are 365 figures; 174 of these are black-and-white diagrams (17), habitat photographs (24), drawings of key features; and tadpoles (for frogs and toads) of various species (133) dispersed through the appropriate sections of text. A section inserted between pages 50 and 51 has 181 colour photographs of individual specimens. In addition, there are 163 text maps, one each of geography and of vegetation, 161 of species distributions with range shown as solid patches.

The herpetofauna includes 188 species: 2 caecilians, 6 salamanders, 36 frogs and toads, 2 crocodilians, 16 turtles (5 marine), 52 lizards, and 74 snakes. The environment is tropical with freezing temperatures unknown and a mean annual temperature generally ranging from about 25 to 26°C. Striking in comparison with herpetofauna in the northern climate of Canada is the presence of the worm-like caecilians and crocodiles, the low numbers of salamanders, and high relative proportion of lizards and snakes. In all of Canada, totals for native species are 21 salamanders, 24 frogs and toads, 13 turtles (5 marine), 6 lizards, and 25 snakes (even the addition of species likely introduced adds only one salamander, three turtles, and one lizard). There are few species in common other than four marine turtles, only the Snapping Turtle (*Chelydra serpentina*), Brown Snake (*Storeria dekayi*), and Milk Snake (*Lampropeltis triangulum*), each represented by a different subspecies from Canadian populations. Other genera in common do not share any species: the widespread *Bufo, Hyla, Rana, Eumeces, Thamnophis, Nerodia, Coluber, Elaphe,* and *Crotalus.*

A major omission is that the contents do not list the species accounts individually nor is any checklist or even keys to the included species provided to summarize the species covered. Individual species have to be searched for through the index. The accounts do not reference individual statements to source, and much more informative spot (locality) distribution maps should have been possible for the area.

For the south-orientated adventurous tourist-naturalist this well-executed and effectively illustrated book provides a welcome guide to amphibians and reptiles and their habitats that may be encountered in

the northern edge of eastern Central America. For the armchair zoogeographer it opens interesting contrasts to familiar northern species and environment. Either in field jacket or bookshelf it is a reference worth referring to repeatedly.

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Dinosaurs, The Encyclopedia. Supplement 2

By Donald F. Glut. 2002. McFarland and Company, Jefferson, North Carolina. 685 pp., illus. U.S. $75.00.

Donald Glut is a dinosaur fanatic. This is obvious, through his published essays (*Jurassic Classics*, 2001, McFarland and Company), his growing compendiums of dinosaur knowledge (for example, *The Dinosaur Dictionary,* 1982, The Citadel Press), and the influence on culture these extinct creatures represent (*The Dinosaur Scrapbook,* 1980, The Citadel Press). In 1997 Glut produced *Dinosaurs, The Encyclopedia* (1997, McFarland and Company). Its 1076 pages was a considerable undertaking. But the problem with any printed encyclopedia, especially in this age of dot.com, is the speed at which information is dated. Resolving this, Glut later published a supplement to the encyclopedia (2000, McFarland and Company). And most recently, *Dinosaurs, The Encyclopedia, Supplement 2* was issued, foreworded by dinosaur expert Phil Currie.

The first hundred pages or so recap and enhance current dinosaur research themes like extinction, the relationships between birds and dinosaurs, and the thermal make-up of these saurians. The bulk of the 687 pages are devoted to descriptions and revisions at the generic level of dinosaurs; new discoveries, new species, and new ideas. And like the first supplement, a section at the end gathers the locations of museums and sites where dinosaurs are prominently showcased. This, however, is a subjective list with several sites absent.

One must applaud the author's continued effort to be on top of all that is dinosaurs. Combined, all three titles (all still in print) total some 2200 published pages and cover the popular dinosaurs like *Albertosaurus* to the less known *Zuniceratops*. Each generic entry reviews the most recent literature. These are followed by "key references", thus avoiding any misconception of being all encompassing. As one would expect with such a mountainous project, typographical errors, or simple omissions are to be expected [in a moment of admitted vanity, the first supplement listed Karen Chin erroneously as the sole author of the paper describing the *Tyrannosaurus rex* coprolite from Saskatchewan]. This aside, included with many of the entries are notes gathered from conversations and lectures, information not usually recorded. In addition, a plethora of photographs and illustrations, many from original publications if not from the author's own collection accompany the entries.

Unlike other substantial and significant compilations like *The Complete Dinosaur* (1997, Indiana University Press), *Encyclopedia of Dinosaurs* (1997, Academic Press), and *The Dinosauria* (1990, University of California Press), if Glut is up to the task, his three volumes and hopefully further supplements, will be the benchmark of dinosaurian synopsis. A big proviso, however, would also rest with the publisher – McFarland and Company. They should be recognized for sticking with Glut's vision and the high quality of the end product.

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The Archaeology of Animal Bones

By Terry O'Connor. 2000. Texas A&M University Press, College Station, Texas. 206 pp. $34.95 U.S.

Terry O'Connor's *The Archaeology of Animal Bones* proves to be a useful guide not only for zooarchaeologists and even paleontologists alike, but for mainstream archaeologists as well. Non-human remains have the potential to reveal "different forms of data inherent in them" O'Connor maintains, "each of which conveys information about the original animal, its life and death, its interface with people, and the complex events and processes which have led to its survival as an archaeological specimen" (page 53). The author covers the breadth of themes in sequence; from taphonomy, excavation, identification, and quantification of specimens, to age at the time of death, pathology, environmental influences and signatures,

to human interaction. The text is straightforward and easy to read, heavily illustrated, and referenced, useful for an introduction to the field.

The Archaeology of Animal Bones confesses to be as broad based as possible in the many approaches to the study of associated bones in archaeological sites, yet it is produced through the experiences of its author. In interpreting body-part analysis for example, O'Connor notes "there is no 'right way' to do it, but by applying a wide range of procedures to the same data sets, we can at least see which patterns in the data are inherent to those data, and which are characteristics of a particular analytical technique" (page 79). This is true for much of the methodology in acquiring the data and their interpretation.

Inadvertently, *The Archaeology of Animal Bones* would be a suitable companion to Steve Roskams British oriented *Excavation* (Cambridge University Press, 2001), though the latter is part of a larger series of archaeological manuals. Admittedly, O'Connor's volume is rich in non-North American examples with modest references to North American sites and research. Yet the clear, step-wise approach by the author, and the broad scientific appeal of the volume makes it highly effective in illustrating the potential of vertebrates in telling a story of the past.

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BOTANY

Rare Native Vascular Plants of British Columbia, Second Edition

By George W. Douglas, Del Meidinger and Jenifer L. Penny. 2002. Crown Publications, 521 Fort St., Victoria, British Columbia V8W 1E7, Canada. 358 pp. $45.00 + GST and postage.

The previous edition which was published in 1998 contained information with distribution maps and excellent line drawings, habitat/range information, Global/Provincial Rank, and status Red or Blue. The Red List included 193 taxa that were candidates for legal designation as endangered or threatened and 42 historic or extirpated taxa plus seven not considered as above but included in the Red List. The Blue List included 357 taxa that could become candidates for the Red List.

In this new edition considerably more information is provided in the Habitat/Range section. The Red List has been increased to 271 taxa and the Blue List to 346 taxa. In addition, many of the maps have been updated and some sites that were previously marked by a black dot have been changed to a black circle to indicate that a taxon has been extirpated or not known from that area for a long time. Additional notes have frequently been added for many of the taxa.

This publication is a tremendous step ahead for the knowledge of the vascular plant flora of the province of British Columbia. I would be more than happy to see similar updated works for any of the other Canadian provinces.

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Flore printanière

By Gisèle Lamoureux with Roger Larose photograph collaborator. 2002. Fleurbec, 198 chemin Grande-Grillade, Saint-Henri-de-Lévis, Québec, G0R 3E0 Canada. 576 pp. $29.95, including GST and postage.

This soft cover book on the spring flowers of the province of Quebec has an absolutely beautiful collection of colour photographs which were taken by 15 photographers: Gisèle Lamoureux (187), Roger Larose (59), Francis Boudreau (12), Camille Rousseau (7), Michel Boulianne (3), Jacques Labrecque (2), Normand Lalonde (2), Claude Allard (1), Yves Boudreault (1), Line Couillard (1), Lucette Durand (1), Alain Giard (1), Miroslav Grandtner (1), and Sylvain Lamoureux (1).

The text of this volume is written in French. The only exceptions to this are an English common name for each species and of course, the scientific names which are in Latin. The first page describes the joy of seeing the beautiful wild flowers which appear in the spring. This is followed by a list of the common names and page numbers as they appear in the text, introductory information including North American floristic habitats and vegetation zones in Quebec and Labrador.

The first section provides two pages for each of 105 wild flowers. The left page is initiated by the French common name in large bold face, followed by an English common name in small face, additional French names in small face, and the scientific name and synonymy with information on the scientific names. This is followed by a description of the plant, its habitats, and other information all of which is wrapped around a small distribution map showing where it occurs in North America, and facing its beautiful picture on the right hand page. Then comes a second section which includes eleven pages depicting flowering trees, and a third section in the same order as Section One with continuing information on the species and many additional photographs. The volume is completed with a glossary, a most useful bibliography, an index to other Fleurbec guides, and an index to this volume.

Overall, this is a most beautiful volume.

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Ecological Management of Agricultural Weeds

By M. Liebman, C.L. Mohler, and C.P. Staver. 2001. Cambridge University Press, New York. xi + 532 pp., illus. U.S. $120.

Agriculture, as cropland and/or pasture, is found in some form whereever mankind settles. A major challenge for agricultural production has been the existence of unwanted plants (weeds) within the stand of desirable plants (the crop). Within the developed world herbicides have been the major method of control and key component of textbooks on weed management. As a result of increased interest in invasive plant species, societal demands for a cleaner environment and sustainable agriculture, non-chemical methods of control are gaining societal support. An indication of such support can be found in the suggestion from the Johannesburg World Summit 2002 indicating dependence on chemicals must be decreased and a more ecological approach to food production be developed. Liebman et al. have written this book specifically focusing on ecologically based methods of management. In the words of the authors they were "able to provide in-depth treatment of subjects that most weed science books treat only briefly."

This in-depth treatment of subjects is done in 11 chapters organized into three main sections. The three main sections focus on: the need for and approach to ecological management; impact of the environment and disturbance; weed evolution, and plant community structure. Each of the chapters has references lists, with some exceeding 250. A sampling of what the chapters include follows: mechanical weed control, increasing crop diversity, biocontrol with livestock grazing, insects and pathogens, and modification of cropping systems to enhance the crops' competitive ability. The contents rely on basic ecology, plant biology, and applied ecology literature.

The authors put forward three objectives for ecological management of weeds: (1) weed densities should be reduced to tolerable levels not eliminated; (2) amount of damage to the associated crop should be reduced with a given weed density; (3) shifting of the weed species or community to a less aggressive and less persistent composition. Having provided the objectives, the authors also supply areas of knowledge needing further research to help meet the objectives.

Ecological Management of Agricultural Weeds in this reviewer's opinion should make an ideal text for an upper year undergraduate or graduate level course. The well researched contents with extensive references could easily provide a good grounding in the subject matter. With increased societal demands to reduce reliance on herbicides and for greater reliance on ecological approaches, the demand for this textbook can only increase. I congratulate the authors in a well timed and well done text.

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Fungal Conservation: Issues and Solutions

Edited by David Moore, Marijke M. Nauta, Shelley E. Evans, and Maurice Rotheroe. 2001. Cambridge University Press, Cambridge, UK and New York. x + 262 pp., illus. U.S. $95.00.

The realization that fungal species (with few exceptions the book concentrates on the macrofungi, such as mushrooms and allies) are experiencing significant declines has made conservation a major concern. Fungi are ubiquitous, they make up a significant part of the microflora in soils, and the roots of most higher plants have a beneficial association (mycorrhizae) with the fungi.

Key words and phrases from some of the chapter titles are: trends and perspectives, nature management, forest fungi, ecosystem, future of fungi, fungi as indicators, threats to biodiversity, valuable, rural economies, survey, national mycological societies, and optimism.

Economically the wild mushroom industry is mushrooming. In 1992, nearly 2 million kg were harvested in the Pacific Northwest of the USA, bringing over US$40 million to the economy (Molina et al.). And the global trade in matsutake alone is estimated at US$3 to 5 billion annually; for chanterelles it is about US$1.5 billion (Aurora). In some communities in China, Bulgaria, Italy, and Zimbabwe wild mushrooms provide 50 to 100% of a family's annual income (Aurora). In Champa (Tibet) the intact, healthy forests are perceived as the key to rural development rather than as an impediment to it (Aurora). Thus sustainable management of the wild mushrooms is critical to the welfare of many towns and villages. Regarding sustainability of harvests, Aurora comments that wild mushrooms, like pine nuts and huckleberries, can be harvested without significantly damaging our forests and that buying them in a gourmet restaurant probably comes at less cost to biodiversity than wine, beef, or almost any other item on the menu.

From committees focusing on global conservation to the effects of wild mushrooms on rural economies, the 22 chapters in this book provide an introduction to the varied problems and proposed solutions to fungal conservation. In the introductory chapter the editors present an overview of the threat to microorganisms and establish that fungi are important. In giving readers perspective on their importance, Staley (1997, Current Opinion in Biotechnology 8: 340-345) is quoted "the tree of life is largely a tree of microorganisms ... much of the diversity on Earth is microbial with the plants and animals appearing as small, terminal branches."

Before solutions can be implemented it is essential to define the problem, and in the case of fungi this has not been easy. Several authors emphasize that effective conservation programs need the input of mycologists (those who know and study fungi) and mycologists are seen in many parts of the world as an endangered species. Public education is discussed as the key to gaining the necessary resources and this is a long term effort. In the more immediate future, Molina et al. argue for the development of a cadre of parataxonomists (those of less formal mycology schooling but trained in fungal identification and methods of study) that can evaluate the mycologically valuable sites.

Courtecuisse, in a chapter titled "Current trends and perspectives for the global conservation, of fungi" gives an overview of the main tools being used by fungal conservationists; i.e., inventories, mapping programs, and Red Data Lists. And these items appear in various forms in all chapters. Several authors bemoan the lack of base-line data on which to judge the present status of diversity or frequency. Jalink and Nauta show how such data can be used to calculate the mycological value of a site. At least 20 European countries have Red Lists for fungi (essentially mushrooms and allies) and, although the criteria for listing may differ, these have been valuable in managing species (Arnolds). Arnolds in an intriguing chapter titled "The Future of Fungi in Europe" presents a wide ranging discussion of many facets of fungal conservation. His discussion of checklists concludes with "Any checklist is better than no checklist." *Nota bene* colleagues who hesitate!

It is disappointing that only one contribution focuses on the Western Hemisphere. However, that seems to reflect the importance given to fungal conservation in the area. Molina et al., in a detailed, thoughtful presentation, deal with the problems, logistical and legal, of conservation in the United States' Pacific Northwest. The presentation concludes with eight guidelines for mycologists to consider when embarking on fungal conservation efforts.

This is a well written book, broad in mycological scope, and the topics are concisely presented. It is a good starting point for anyone interested in fungal conservation and should be required reading for North American ecologists, plant diversity researchers, land managers, and foresters.

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ENVIRONMENT

Two Hundred Years of Ecosystem and Food Web Changes in the Quoddy Region, Outer Bay of Fundy

By H. Lotze and I. Milewski. 2001. Conservation Council of New Brunswick, Fredericton. 188 pp. $30.

The Bay of Fundy is a Canadian and international jewel. This book presents one of the best and most updated compilations and analyses of various relevant topics for a fascinating, outstanding, and very productive ecosystem, the Quoddy Region. Besides classical subjects such as fish, sea mammals, birds, and oceanography, this landmark publication even adds several new topics of interest for the ecological integrity of "the Bay", such as archeology (humans), benthos, marine plants, plankton, species extinction, whaling, and sealing.

Many indicators of environmental health and ecosystem integrity are thoroughly investigated by the authors. All indicators convincingly show that the Canadian North Atlantic was treated as badly as any other of the major fishing grounds in the world; the Bay of Fundy and its Quoddy Region are no exception. The authors present compelling, if not final, evidence for this fact. Lobster catches steeply increased in Eastern Canada during the last years, providing the American market with a highly-priced commodity; it is very hard to believe that this harvest could be on a sustainable level.

This book is another unique compilation of interpreted information and data sources proving convincingly how human activities have altered the planet. From the Passenger Pigeon, over the Labrador Duck and Great Auk to the Sea Mink; all of these animals were creatures of the Bay of Fundy region that were wiped out by poor management of natural resources and by human greed within few generations. However, when taking into consideration the Canadian realities such situations should perhaps not be judged too easily. Harsh environments deserve different perceptions and judgments, different than those that are easily done in convenient cities and offices. This appears to be a slight weakness of this book: the authors see changes in the light of good or bad, right or wrong. Most population declines are "bad" and increases are "good", or they are not further discussed. The overall paradigm of the book that "native species are good, Europeans are evil", could be put into doubt. In contrast to what is presented in the book, it could be possible that animals in an "undisturbed" environment (already a debatable term as such) were only abundant in low numbers, and that population increases, often interpreted as a "recovery" or safe situation, present something very bad. The current Atlantic-wide extension of the Northern Gannet population is such an example, increasing Cormorant numbers in the Bay of Fundy are another one. An increase is not always good or natural; it is well known that marine habitat degradation such as overfishing can trigger the high abundance of small prey, which increases many waterbird populations. Small-scale signals, such as found in the Bay of Fundy Quoddy Region, need to be seen and interpreted in their global context. The question why Atlantic Right Whale populations, fully protected for many years now, are still not "exploding" remains unanswered.

The authors provide a powerful message on how the Bay of Fundy region was altered in the last two hundred years. The decline of herring in the Bay of Fundy is considered already a traditional trend. Here another supporting argument to underline these facts: harvesting down the food chain has now reached the plankton and rockweed level. The promotion of pure economic growth is of no value to anybody who needs to make a sustainable living from the Bay of Fundy and its resources.

Besides compiling many references and information about food webs and the ecosystem of the Quoddy Bay, the authors also present very interesting reviews on whaling and sealing. It would be great to make the wonderful literature reference selection (24 pages strong), and the compiled raw data, accessible to anybody; e.g., via a database on the Internet/WWW.

This book demonstrates the tremendous value of long-term data sets. Unfortunately, for most important management questions such as populations of fish and bird species or habitat quality monitoring, these databases are missing, were not derived from a rigorous statistical design, or were never maintained for the entire Bay of Fundy. However, such high quality monitoring data are still needed and a crucial requirement for any sound management, and certainly for a sustainable nation. Instead, we are forced in many cases to make interpretations from commercial fisheries catching and harvest data. These ones are really flawed (e.g., by technology and market demand) and therefore they are almost not interpretable, presenting nothing more than pseudonumbers of low ecological value. The book compensates for this problem somehow by analysing as many data sets as possible.

The book shows that success stories regarding the poor state of the Bay of Fundy's health are few, and normally driven by the need of managers to produce "progress". For instance, stocking fish is not a solution at all; this is well proven elsewhere and even considered to be harmful for the fish stocks as well as for the habitats. Other "success stories" have reached over the years a point that they become ironic; e.g., recovery of groundfish, international

conservation issues of the St. Croix river, and dams affecting runs of Gaspereau and salmon near Moncton or in the St. John river. If the dams were gone (or opened), the fish would do fine.

The contributions of this book are manifold: small formatting and figure errors can easily be forgiven, even that a U.S. perspective is not included (the Quoddy Region has a substantial U.S. border). After the publication of this book, it becomes obvious that the science is done, what's needed now is action. Boldly spoken, the Irving company is still running its refinery and pulp and paper mill in the traditional way, which contributes to the reputation of St. John's as the "armpit" of Canada. But no wonder when an industry is allowed to monopolize the regional newspapers and the political and job scene. To the general surprise of the many (international) visitors, pulp and paper mills are still releasing their waste water in the rivers and Bay of Fundy, a nuclear power plant is located right at the waterfront, and aquaculture is promoted. Although the city of Moncton had severe *E. coli* outbreaks, there is still no major sewage treatment approach put forward for the watershed of the Bay of Fundy. This should be embarrassing to any Canadian citizen, and certainly to any informed conservationist, manager and politician, to say the least. It is fortunate that this publication was made possible by different (private) funding agencies and NGOs (e.g., Conservation Council of New Brunswick). The authors can be congratulated for their achievements. They conclude that "there is no evidence of an ecological simplification of the entire food web defined as the loss of an entire trophic level or functional group. But, the food web is severely altered and we find strong shifts in species composition and dominance patterns that affect predator-prey, habitat and competitive relationships". It is now up to us to restore and to save the Bay of Fundy from even more harm.

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Autumn, A Season of Change

By Peter J. Marchard. 2000. University Press of New England, Hanover, New Hampshire. 151 pp., illus. + plates. Cloth U.S.$50; paper U.S.$17.95.

This book, by field biologist and biology professor Peter J. Marchand, is a remarkable natural history work. It takes one season, autumn, and looks at it from such diverse and fascinating angles — some which never would have occurred to me — that my head is still reeling from all I've learned.

That's not surprising. I couldn't have known about all those things because I'm not a scientist. But Marchand is, and he's an awfully good writer too (and philosopher, and photographer), who manages to render complex chemical and biological processes understandable to a non-scientist like me.

In the book, Marchand focusses on the terrestrial environments of his personal experience. He illuminates various autumn phenomena through fifteen essays on topics such as freezing, senescence, dispersal, migration, the fall rut, autumn in ponds, harvesting activities, and more.

I discovered all sorts of fascinating things in this book. From the wide array of light-sensitive pigments in plants, to the biochemistry behind fall colours. From the diversity of molting processes in mammals and birds, to leaf self-amputation. From intracellular ice formation in plants, to freeze avoidance and tolerance in insects. From the factors prompting bird migration, to the impressive journeys of insects. From the stakes involved in the fall rut, to the risks of hibernation. From amazing fall harvest accomplishments among mammals, to the highly involved process of leaf decomposition.

Marchand the poet and philosopher comes out in passages like "For the apparent disappearance of many plants and animals, autumn is often seen as an end. But the seasons are part of a continuum, a revolving process of birth, death and renewal — and if such could be said to have any beginning or end, then fall could just as well be viewed as a beginning."

Speaking of poetry and philosophy, Marchand sprinkles his essays with passages from the works of late great nature writers such as John Muir, Henry David Thoreau, and John Burroughs. And the author's own black-and-white photographs add additional touches of creativity. As Marchand writes in the preface, "while the book is primarily concerned with nature and science, it also about art, literature, and a smattering of philosophy, because to discuss science in isolation from these would be something like studying the life of a flying squirrel in a cage; fruitful to a point, but missing essential context."

Marchand creates a most fascinating autumn context in this book — one that both delights and teaches. *Autumn, A Season of Change* is certain to become a well-thumbed resource in my natural history library.

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Making Parks Work: Strategies for Preserving Tropical Nature

Edited by J. Terborgh, C. van Schaik, L. Davenport, and M. Rao. 2002. Island Press, Washington. xix + 511 pp., illus. Cloth U.S. $65; paper U.S.$32.50.

This book contains 32 chapters by a variety of authors on management of parks in the tropics. These result from a meeting in Florida in August 1999 of 30 tropical park conservation experts. The book has a purpose as a reference guide for field workers. The book is divided into four parts: (i) introduction – 3 chapters; (ii) case histories – 14 chapters; (iii) themes – 13 chapters; and (iv) conclusions – 2 chapters.

The introduction defines the need for parks. The overall theme is that extinction rates are growing continuously under increasing population growth, especially in tropical regions. Parks are essential for the protection of many of the more susceptible species. The most ecologically diverse areas are always the most fertile areas, which are thus most in demand for agriculture. The most critical species are often the larger animals, which usually require larger areas to graze or to hunt and are usually less tolerant of human interference. Very strong opinions are expressed that attempts to integrate conservation and sustainable development just do not work. The concept of the "noble savage" with an innate desire to conserve nature, is also debunked. These are both very pertinent to me, as I am reviewing this book while attending a workshop, sponsored by the World Bank, relating to management of endangered environments in tropical Africa. The workshop is taking place in Yankari National Park, Nigeria, where I can listen to elephants and lions, as well as other large animals, in the evening. A large part of the discussion relates to involving local villagers in sustainable development and environmental management. The concepts that this book is opposed to are being strongly endorsed at this workshop. I am not sure who is right, but it does seem the sustainable development concept is crumbling under Nigeria's rapidly expanding population with the highest priority to many being to keep from starving. I do agree with the conclusion that attitudes (at all levels of society) and institutional capacity are critical to the success of tropical parks, but am less in agreement with the concept put forward that foreign investment, with financial compensation for loss of land, is a good way to resolve the problem.

Many case histories are presented from around the tropics. I found these very informative with useful examples of what has succeeded and what has failed. It is also interesting how very different methods succeed or fail in different societies. For me, it was disappointing to not see any examples from Nigeria – the country with the largest human population and most diverse environment, as well as some of the most environmental loss in all of Africa. The only West African examples were all related to the rain forest environment and primate species. Yankari NP, where I was sitting to read this, is savannah, but still has many recent local extirpations, some major habitats and wildlife species, as well as significant human-wildlife interactions. The elephants have found a liking for watermelons. I have not seen one eat a watermelon yet, but can picture some comical approaches. They have also discovered that they are bigger than the farmers who try to chase them off. This can have disastrous results. The case histories include five from Africa, four from Latin America, and four from Asia. Interesting are the case histories where parks have succeeded. The most intriguing are the private parks of Costa Rica, deriving success largely from ecotourism values.

The third section of the book, on Themes, has some excellent examples and recommendations. Very worthwhile topics for tropical park planners include mitigating human-wildlife conflicts, enforcement (which is generally felt to not work), ecotourism, financing, and monitoring conservation efforts.

For my work in protecting African parks and environment, this is a most useful reference. It might be interesting to those involved in park conservation elsewhere or just interested in the tropical environment, but it is rather specialized and probably of limited interest to the average Canadian field-naturalist.

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Thoreau's Country: Journey Through a Transformed Landscape

By David R. Foster. 2001. Harvard University Press, Cambridge, Massachusetts. 270 pp, illus. U.S.$16.

Naturalist and author Henry David Thoreau (1817–1862) is revered today as one of America's first environmentalists. His journals of his days in the fields and backwoods of early nineteenth century New England were shaped and informed by an ecological consciousness that was unusual for the time and place. Indeed, his observations – and more importantly, his musings – have inspired all kinds of conservation activities in his name.

But as David Foster, Director of the Harvard Forest, argues in *Thoreau's Country*, the world that Thoreau painstakingly documented in *Walden* and other works is no longer recognizable. The pastoral setting is now a forested landscape — quite different from the countryside that Thoreau once understood and appreciated.

Foster tells the story of this transformation through a generous mixture of quotations from Thoreau's journals and a series of reflective, engaging essays on a variety of topics (meadows, wood lots, fires, animals, and even fences). In reading the sections, it quickly becomes apparent that Thoreau was actually describing a landscape with a heavy human footprint. It is also clear that the New England woodlands today are closer to the kind of landscape commonly identified with Thoreau, but ironically, not the one he intimately knew and enjoyed. As Thoreau himself once observed, "man's works fall into nature."

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Voices for the Watershed: Environmental Issues in the Great Lakes – St. Lawrence Drainage Basin

Edited by G. G. Beck and B. Littlejohn. 2000. McGill-Queen's University Press, Montreal and Kingston, For the Wildlands League, Canadian Parks and Wilderness Society, Toronto. 299 pp., illus. $39.95.

Having been involved in a task on the biodiversity of the fishes of the Great Lakes, I assume it was the subtitle of this book that caught my attention. My overly narrow view led me to be unprepared for the nature of the book. The book is an outgrowth of participation by Littlejohn, ostensibly as a photographer, on a cruise of a U.S. research vessel working on the St. Lawrence River and the Great Lakes. The purpose of the cruise was both study and education, and it involved a number of mainly earth scientists with a breadth of professional interests. The concept for the book involved the following points: (1) scientific knowledge made available to the public in an understandable style; (2) a complete watershed approach: (3) a cross-boundary effort involving writers from various U.S. states, Ontario, and Quebec, with an awareness of the impact on the watershed of what is done, and is not done; (4) wide range of topics, the bad news and the good; (5) public awareness of, and identification with, the watershed and specific parts of it; (6) scientific, ecological, conservation, and restoration activities; (7) broadscale citizen involvement to improve the health of the watershed.

It is difficult to review the book other than in a general way. It includes a brief Foreword by Monty Hummel of World Wildlife Fund Canada. The bulk of the book is organized in two Sections. Section 1, Voices for the Watershed, begins with a brief Prologue by Bruce Conn emphasizing science and society working together for environmental understanding. This is followed by a more extensive introduction by the editors. The articles in Section 1 are organized under headings Headwaters and Uplands Regions, The Great Lakes, The St. Lawrence River, and Watershed Perspectives. This section includes 31 articles, divided by both subject and geography. The length of individual articles varies from 2 to 2½ pages (Rescuing Native Fish and The Acid Rain Story) to an average of 5 to 8 pages. Section 2 is headed Finding a Voice. That section includes an article entitled Revelations: The Evolution of an Environmental Ethic and Career, by Michael Keating (33 pages). An Epilogue by Bruce Littlejohn (11 pages), and the Appendices are included in this Section. The latter involve a list of environmental agencies, references, brief author biographies, acknowledgments, and index. There is a high quality and very detailed map of the watershed at the beginning of the book. It, and some of the articles, emphasize the more recent recognition of the reality of the Finger Lakes, Adirondack Park, and Lake Champlain system as parts of the Great Lakes-St. Lawrence Watershed.

The editors took pains to emphasize that the intent of the project was to reach far beyond the level of providing information, and expressed the hope that the numerous "voices" will motivate and inspire the

reader, as an individual or as part of a group, to become actively involved in helping to protect the watershed and drainage system. They stated that the book is not intended for environmental experts or scientists. They suggested that for that reason the authors are largely those trained to write for the general public.

I was very pleased to see the emphasis by John Jackson on "Bi-National Citizen Action". Working with the Natural Resource agencies of the various political areas involved in the watershed too often reveals a tendency for each to go its own way rather than recognize they are all involved in the concern for, and the stewardship of, a single, shared ecosystem.

The Editors and authors of this book have achieved, to a moderate extent, their stated goals since they rightly insist the future is up to the response of the citizens. I enjoyed the suggestion of Lavigne and Gates that all of us need to know our "Ecological Address" which is somewhat akin to our Individual Environmental Footprint. There are many citizens and students only partly aware of the ecological problems of our waters and of his/her responsibilities in that regard.

The size of this book may daunt some potential readers. Others may be discouraged by the unusual nature and brevity of a number of the articles. However, if they read selectively, emphasizing the Introduction and Prologue, they will understand much better their responsibility and role in the protection and wise use of this extremely important freshwater resource. In that case the Editors and authors will have reached the goals we share with them.

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Conservation of Exploited Species

Edited by John D. Reynolds, Georgina M. Mace, Kent H. Redford, and John G. Robinson. 2001. Conservation Biology. Number 6. Cambridge University Press, New York; Wildlife Conservation Society; and The Zoological Society of London. xx + 524 pp., illus. Cloth U.S. $120;, paper U.S.$44.95.

What happens when we try to redress the harm we have already done to an exploited species by initiating conservation measures? The use of wildlife for food and other human needs poses one of the greatest threats to the conservation of biodiversity. However, wildlife exploitation is also critically important for subsistence and commerce by many people. In this text book international experts examine interactions between the biology of wildlife and the divergent goals of people involved in hunting, fishing, gathering, and culling wildlife. Many theories are presented showing how sustainable exploitation is tied to the study of population dynamics, with direct links to reproductive rates, life histories, behaviour; and ecology. Unfortunately many of the theories are rarely put into practice to achieve sustainable use and successful conservation. For instance, in the Arctic it is difficult to monitor animal population decline and set legal limits for hunting, which are usually determined when a population has already declined. There is growing use of hunters' knowledge though, and at least they are an effective voice in Arctic wildlife conservation.

There is a dramatic change in a whole community when a species becomes extinct or endangered. It changes the dynamics of population growth for the endangered species, and there is a cascading effect. One example is, for instance, sea otters which eat sea urchins which in turn eat fleshy algae. Lose the otters and the increased population of sea urchins will kill the kelp forest. Again, problems occur when there is increased agriculture on land outside a wild game reserve. Since this land is usually marginally productive, the land further degrades. A more subtle cascading effect occurs if the population of bees is reduced. Only the most nectar laden flowers get pollinated and "low-ranked flowers" will not be pollinated. If wildlife hunting is controlled, hunters will select the biggest and best specimen to shoot. Over time this results in the species becoming smaller through the loss of genes and body mass. An interesting chapter gives the results of a study of sustainable use and control of kangaroos in Australia. Kangaroos have been aggressively hunted on sheep ranches, but the study shows that it is more profitable to farm kangaroos and sell their meat and hides than to raise sheep!

Even though this book is meant for biology students, it has much to interest anyone working in wildlife conservation. The moral seems to be "Conservator Beware"!

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Politics of the Wild: Canada and Endangered Species

Karen Beazley and Robert Boardman. 2001. Oxford University Press, Toronto. vii + 254 pp. $27.95.

As the title suggests this book focuses on the politics of endangered species conservation in Canada although it does not neglect the scientific background of threats and conservation needs of species at risk. It was written under the shadow of the federal government's second failed attempt to deliver endangered species legislation and is therefore in some ways already outdated. Nonetheless it provides a fascinating analysis of the social and political complexities of endangered species conservation which are no less challenging now than they were before the third attempt was passed by the House of Commons in June 2002. (It subsequently received Royal Assent December 2002 and will come into force by an order in council in 2003)

The book is divided into two parts entitled "From Philosophy to Science" and "From Science to Policy". In the first chapter of part one, co-editor Beazley provides a clear summary of the various philosophical arguments in favour of protecting endangered species, and explains the strengths and weaknesses of each argument. This is followed by a useful but uninspired summary of the, then current, status of species at risk in Canada. The third chapter, on the importance of habitats and ecosystems, is the most disappointing, being almost incoherent in places. An appendix listing the legislation, policy and programs relevant to endangered species for the federal and each territorial and provincial government is somewhat useful though apparently incomplete. Policies and programs are only listed for British Columbia and Alberta. An additional appendix apparently summarising a gap analysis report provides neither a reference to the original report nor definitions of key jargon. The last two chapters in part one review the history and current status of terrestrial and marine protected areas respectively.

Part two forges bravely into the murky waters of politics. The first two chapters in this section examine the history of endangered species conservation and politics in Canada, and the federal government's efforts to create federal endangered species legislation. Of particular interest in the former is the historical trend towards increasing application of science to species designation, recovery efforts, and systematic habitat protection. The latter chapter explains clearly the role of various players in negotiating legislation including an assessment of the effect of scientific opinion (minimal). It also provides an intriguing table comparing the two defunct bills (C-65 and C-33) on the basis of their characteristics and how NGO's (Non-Governmental Organizations) landowners and industry, and the provinces viewed these characteristics. It would, of course, be nice to have the current bill included in this comparison but that will have to wait for a future publication.

The next two chapters take an international perspective. In the first, the politics of species at risk is compared among OECD (Organization for Economic Co-operation and Development) countries with Canada being most similar to Australia but all countries sharing many of the same difficulties. The subsequent chapter addresses the intriguing question of how signing international agreements affects domestic policy with CITES and the Convention on Biological Diversity used as examples. There is no simple answer here. The final chapter provides a summary overview of the complex political processes discussed throughout the book and concludes that these processes will continue to shape endangered species conservation in the future.

I recommend this book to anyone working actively in wildlife conservation. It covers issues often thought of as peripheral to the biology of conservation yet critical to the success of any recovery program.

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MISCELLANEOUS

On Her Own Terms: Annie Montague Alexander and the Rise of Science in the American West

By Barbara R. Stein. 2001. University of California Press, Berkeley, 380 pp., illus. U.S. $35.00.

Early 20th century was a time of major development in terms of technology, education, and human settlement. These were especially prevalent in the North American West Coast. With the establishment of new communities in California and the prosperity therein gained, culture and education also emerged alongside. One example of the philanthropic nature supporting the cultural and educational enhancement is reflected in the life long contributions of Annie Alexander (1867–1950), daughter of the Hawaiian

sugar cane baron Samuel Alexander. Her contributions, however, exceeded most other benevolent magnates in that her support for research activities at the University of California also included a more practical nature including the personal collecting, identification of thousands of floral and faunal specimens, extinct and extant.

Barbara Stein's *On Her Own Terms* is more of Alexander's accomplishments as a contributor to science and education rather than an all-encompassing biographical tome. For that of a personal nature (for example, her relationship to her companion and fellow collector Louise Kellogg), one is left with too many assumptions as all surviving documents are of a professional composition. Yet Stein, maintaining her focus, is able to document the vastness of Alexander's knowledge, experiences, as a woman scientist who "lived passionately, and perhaps most importantly . . . [dealing] with the world on her own terms" (page xiv).

Being the daughter of wealth allowed her the opportunity and means to enhance and experience natural history from a practical, first hand view. One of her early adventures while in her 30s allowed her to partake in an African hunting safari with her somewhat unconventional father. Her father's view of Annie was of an intellectual equal on these ventures; a participant rather than an escorted tourist. Resources also allowed her to attend university classes as a "visitor", thus enhancing her own interests.

The untimely death of Annie's father on the African safari, however, left a void that was only filled by following through on a vision; first, the establishment of a natural history museum on the campus of the University of California. Its mandate would be for research and scientific publication. The nucleus of its collection would be her 3400 specimens and if the university would pay for the building, she would pay for salaries and expeditions. This was keenly played on Annie's part as it allowed her to have control over the research. The 3400 specimens and the thousands more she would contribute directly or through funding expeditions, has made the Museum of Vertebrate Zoology one of the most impressive collections in North America.

Her interest in contemporary fauna and flora yielded only to her interest in fossils. Her participation in the collection of Mesozoic vertebrates, for example, left her hoping that "I wish my work went further than to simply get the fossils to the university. I should like to follow the saurian . . . to the bitter end. chisel him out of the rock and write learned treatises on his venerable anatomy" (page 19). Her fondness for paleontology would have blossomed further, even after founding the University of California Museum of Paleontology, if it were not for the personal embattlements between her and the administration. The university's initial lack of interest would lead her to exclaim, "paleontology is a foundation science yet it takes a rather spectacular quest . . . to arouse the interest of the [university] administration" (page 180). Still, she contributed specimens, and salaries and financed expeditions.

A beckoning question is why a broader audience does not know her? How many individuals in the last century contributed thousands of dollars to one research facility, and thousands of personally collected specimens spanning the breadth of natural history? The bulk of Annie's anonymity comes from Annie Alexander herself. All her donations were to be kept as confidential as possible. As Stein surmises "Alexander was raised in an atmosphere where benevolence was expected but not touted" (page 117). It is unlikely that her anonymity was in any way linked to her own intellectual insecurities (though all admitted that she was of highest ranking among field biologists). "While she felt passionate about science", Stein writes, "she clearly seemed to favor physical activities over those that were cerebral" (page 92).

On Her Own Terms is definitely worth reading. A pioneering, early 20th century woman making waves in the male-dominated world of science (and society) is always worth understanding and appreciating. Stein portrays her as a strong minded, generous contributor and patron of the sciences. Her grand vision and control of the development of the natural sciences at the University of California is only matched by her benevolence, even in spite of those who disagreed with her. A remarkable, if not contradictory person.

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News and Comment

Froglog: Newsletter of the Declining Amphibian Populations Task Force (53)

October 2002. Contents: DAPTF Seed Grants 2003 — RANA: The Research & Analysis Network for Neotropical Amphibians — RANA: Red de Analisis sobre Anfibios Neotropicales Amenazados (Bruce E. Young and Karen R. Lips) — Global Amphibian Specialist Group (GASG): Mission and Functions — Publications of Interest — Froglog Shorts.

Froglog is the bi-monthly newsletter of the Declining Amphibian Populations Task Force of The World Conservation Union (IUCN)/Species Survival Commission (SSC) and is supported by The Open University, The World Congress of Herpetology, and Harvard University. The newsletter is edited by John W. Wilkinson, Department of Biological Sciences, The Open University, Walton Hall, Milton Keynes, MK7 6AA, United Kingdom; e-mail: daptf@open.ac.uk. Funding for *Froglog* is underwritten by the Detroit Zoological Institute, P. O. Box 39, Royal Oak, Michigan 48068-0039, USA.

Marine Turtle Newsletter (98)

October 2002. Contents: ARTICLES: Preliminary Check-List of the Epizootic Macroalgae Growing on Loggerhead Turtles in the Western Mediterranean Sea — Recent Sightings of the Green Turtle *Chelonia mydas* on the Coast of Andhra Pradesh, India — Cayman Turtle Farm Head-starting Project Yields Tangible Success; NOTES: Results of Experimental Carapace Tagging — Observation of Accidental Capture of a Loggerhead Turtle by Hand-line Fishing in Kefalonia, Greece — Green Turtle Encrusted with White Matter Observed Nesting at Akyatan Beach, Turkey; MEETING REPORTS; BOOK REVIEW; ANNOUNCEMENTS; NEWS & LEGAL BRIEFS; RECENT PUBLICATIONS.

The *Marine Turtle Newsletter* is edited by Brendan J. Godley and Annette C. Broderick, Marine Turtle Research Group, School of Biological Sciences, University of Wales, Swansea, SA2 8PP Wales, United Kingdom; e-mail MTN@swan.ac.uk; Fax +44 1792 295447. Subscriptions to the MTN and donations towards the production of MTN and its Spanish edition NTM [Noticiero de Tortugas Marinas] should be sent to Marine Turtle Newsletter c/o Chelonian Research Foundation, 168 Goodrich Street, Lunenburg, Massachusetts 01462 USA; e-mail RhodinCRF@aol.com; fax + 1 978 582 6279. MTN website is: <http://www.seaturtle.org/mtn/>.

Point Pelee Natural History News 2(3)

The fall 2002 issue contains: ARTICLES: Turtle Research at Point Pelee National Park (Connie L. Browne) — Noteworthy Bird Records: June to August 2002 (Alan Wormington) — Brown Pelican: New to Point Pelee (Peter S. Burke) — Point Pelee Butterfly Count: August 10, 2002 (Dan Dufour) — Late-Season Butterflies at Point Pelee: Why Here? (Alan Wormington) — IN THE FIELD — NEWS AND ANNOUNCEMENTS — UPCOMING EVENTS AND OUTINGS.

This newsletter for Point Pelee National Park, Ontario, is edited by Alan Wormington (e-mail: wormington@juno.com). Editorial Assistants are M. Lea Martell and Matthew J. Smith. The web site is www.wincom.net/~fopp/Natural_History_News.htm. Subscription rates are Canada: CAN $15 (one year) or $30 (two years); International: US $15 (one year) or $30 (two years). Send payment (and e-mail address, optional) to The Friends of Point Pelee, 1118 Point Pelee Drive, Leamington, Ontario N8H 3V4 Canada. Issues are mailed in March, June, September, and December, and back issues are available for $15 per Volume/ $5 per issue (postage paid).

Recovery: An Endangered Species Newsletter (22)

The October 2002 issue contains: RECOVERY HIGHLIGHTS: Plovers return home; Reptile recovery; NEWS BITES: Marmot rebounding; COSEWIC Update; CITES Update; RENEW Update; ESRF update; PROFILE: National parks protect species at risk (Leah de Forest); SPECIAL REPORT: New fund established (Recovering B.C. Plants; Restoring frog habitat; Recovering the Piping Plover; Sydenham River recovery; FIELD NOTES: Translocating badgers (Ian Adams); Breeding Wolverines (Sylvie Bouchard); New teams established; ANNOUNCEMENTS: Awards; New publications; Correction; Upcoming events; Site seeing; FEATURED SPECIES: Protecting endangered fish (Mike Pearson).

Canadian Wildlife Service, Environment Canada, Ottawa, Ontario K1A 0H3. Web site: www.cws-scf.ec.gc.ca/es/recovery/archive.html.

National Recovery Plan (23) Long's Braya (*Braya longii* Fernald) and Fernald's Braya (*Braya fernaldii* Abbe)

The Recovery of Nationally Endangered Wildlife [Canada] has issued its "National Recovery Plan for the Long's Braya (*Braya longii* Fernald) and Fernald's Braya (*Braya fernaldii* Abbe)" as Number 23, September 2002. 33 pages. It was prepared by Marilyn F. E. Anions on behalf of the Braya Recovery Team. Copies are available from Recovery Secretariat, c/o Canadian Wildlife Service, Environment Canada, Ottawa, Ontario K1A 0H3; Tel 819-953-1410; Fax 819-994-3684. E-mail: RENEW-RESCAPE@ec.gc.ca.

Response Statements for Extirpated, Endangered and Threatened Species Listed by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) in 2001

This 65-page booklet documents existing conservation measures that federal, provincial, and territorial jurisdictions have in place to protect and/or recover 32 species or populations of species of fish (6), amphibians (4), reptiles (3), birds (4), mammals (3), molluscs (2), mosses (2), vascular plants (8) newly assessed in 2001 by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) as extirpated (1), endangered (13), or threatened (18).

Copies are available from Recovery Secretariat RENEW-RESCAPE@ec.gc.ca. See http://www.speciesatrisk.gc.ca/sar/effors/index.htm.

Recovery of Nationally Endangered Wildlife 2001-2002 Annual Report

Contents: Report from Co-Chairs — Highlights of 2001-2002 [Of 118 Endangered, 94 Threatened, and 17 Extirpated species on the November 2001 COSEWIC list: 83 have recovery teams totalling 468 team members, 14 have final recovery strategies or plans, 68 have recovery plans or strategies in development, 85 are the direct focus of recovery efforts, 42 others are included in ecosystem recovery, 22 show stable or increasing population trends, $26.2 million expended on recovery (salaries + expenses), employment equivalent to about 158 salaried and 18 volunteer people working full-time, and 196 organizations have made financial contributions; 167 public consultation sessions were organized by recovery teams, 22 recovery teams are incorporating Aboriginal Traditional Knowledge or community knowledge into recovery planning] — Stewardship and Recovery [web portal www.stewardshipcanada.ca] — Status of recovery (summaries for 93 species, 6 ecosystems and 2 Conservation Programs or Landscape Scale Initiatives Benefiting — Financial contributors — Funding per Species or Group — Canadian Wildlife Directors Committee. The report was produced by the Canadian Wildlife Service in cooperation with the provinces, territories, Fisheries and Oceans Canada, Parks Canada Agency, authorized Wildlife Management Boards and many individuals and non-government groups.

The Ottawa Field-Naturalists' Club Awards for 2001

At the Club's Annual Soirée, held on 26 April 2002, at the Unitarian Church of Ottawa, awards were once again given to members, and non-members, who have distinguished themselves by accomplishments in the field of natural history and conservation, or by extraordinary activity within the Club. The following citations, a few somewhat abbreviated, were read to the members and guests assembled for the event.

Honorary Member – Dr. John B. Theberge

This honorary membership acknowledges achievements going back more than 30 years. Dr. John Theberge has made outstanding contributions to Canadian natural sciences and to the protection of important Canadian natural landscapes. Beyond that, however, he has also effectively brought to the public eye many important natural history issues through numerous books and articles via television and radio, and through a series of engaging and effective speeches from coast to coast.

Dr. Theberge is a world authority on the ecology of wolves. With the unflagging and expert collaboration of his wife Mary Theberge, John has spent decades developing a substantial portion of the scientific underpinning for the conservation management of wolves in North America. He has particularly focused his work on the wolves of Ontario's Algonquin Park, a remarkable population variously described as a unique form of Timber Wolf, as the last truly wild element of the endangered Red Wolf or even as a distinct species. John's studies of the relationships between wolves and their environments in Algonquin Park, in the Canadian north and elsewhere, have provided challenging research opportunities for dozens of students. A number of these students have gone from the solid scientific and inspirational foundation provided by Dr. Theberge's academic leadership to develop successful careers in Canadian biological sciences.

Dr. Theberge is also well-known for his contributions to park establishment. His careful scientific documentation, effective political lobbying and eloquent persuasion were highly influential in the protection of several globally important natural areas in Canada's north, most notably Kluane National Park in Yukon. His technically accurate and at times lyrical book "Kluane, Pinnacle of the Yukon" attests to his understanding that public awareness and 'buy-in' are important elements of such conservation initiatives. And this conservation focus does not apply only to northern areas. That is demonstrated by his editorship of the beautiful and authoritative *Legacy: the Natural History of Ontario,* as well as numerous contributions to scientific journals across North America, including *The Canadian Field-Naturalist.*

Dr. Theberge was a professor of ecology and environmental studies at the University of Waterloo from 1972 to 2000. He has received many conservation awards during his career. At the close of his speech accepting the Harkin Conservation Award from the Canadian Parks and Wilderness Society, he led the audience in a group wolf howl, saying, "This is a bonding for all of us who work for wild places." He has demonstrated mastery in both the sciences and the arts and has applied these exceptional skills to a greater purpose: the preservation of biodiversity. The natural and wild landscapes of Canada will benefit indefinitely from this exceptional record of scientific and conservation achievements.

Conservation Award, Member – David White

The quest to preserve ecologically sensitive lands is made that much stronger when supported by convincing scientific data, including area inventories of fauna and flora. David White has committed much of his time, energy and expertise over many years to collecting such data, greatly contributing to our knowledge of this area's ecological diversity.

David's documentation of the special botanical features of such areas as the Constance Bay sand dunes, Purdon Fen and Innis Point alvars, all well-known to Ottawa naturalists, have supported conservation protection efforts in these important habitats. His work has also led to ANSI (Areas of Natural and Scientific Interest) designations at Constance Bay and the Burnt Lands.

David's less well known, but equally important, on-going studies of the vascular flora of Lanark County have been pivotal in conservation efforts in that county. David has become the floristic authority for this ecologically complex but poorly documented area of Ontario. He now has documented the presence of approximately 1200 plant species in the county, and the Lanark list has become a key component of a province-wide floristic atlas. David's floristic work is providing valuable resource information for various local conservation initiatives such as conservation/protection arguments for various natural environment assessments, for example, the Highway 7 upgrade planning and highway service road design studies in the Carleton Place area by various environmental consultants.

David has published dozens of articles on botanically interesting and important natural areas, including many contributions to *Trail & Landscape.* He is also co-author of the well-known and much-used 1978 *Checklist of Vascular Plants of the Ottawa-Hull Region, Canada,* and the important 1993 publication, *Invasive Plants of Natural Habitats of Canada.*

We are pleased to acknowledge the many contributions David White has made to the preservation of natural areas and to the further understanding of our botanical legacy, by presenting him with the 2001 Conservation Award for OFNC members.

Conservation Award, Non-Member — Land Preservation Society of the Ottawa Valley

(President Marc Stabb accepted the award on behalf of the Society)

The Conservation Award for a non-member to the Land Preservation Society of the Ottawa Valley for its hard-won victory in saving Gillies Grove, a magnificent old-growth forest in Arnprior, from falling victim to a housing development. The community's struggle to save Gillies Grove was taken up by the Society although it faced the formidable challenge of raising half a million dollars in a small local community for the outright purchase of the forest. It took several years of unrelenting effort, before this goal was finally realized. The focus of the struggle then changed to one of negotiating to balance several conflicting interests: the real estate ambitions of the landowner, the revenue base of the town of Arnprior, and the need to impose land-use restrictions that would safeguard the integrity of the old-growth forest. Year after year, negotiations faltered as new objections or new obstacles were raised, dashing the hopes of the Society and the community. The Land Preservation Society refused to give up, adamant in its resolve that this old-growth forest must not be sacrificed to development. After an epic eleven-year struggle, the unswerving commitment of the Land Preservation Society of the Ottawa Valley resulted in the purchase of Gillies Grove by the Nature Conservancy of Canada in December of 2001, with stewardship of the forest undertaken by the local Macnamara Field Naturalists' Club.

From all of us in the Ottawa Field-Naturalists' Club to the Land Preservation Society of the Ottawa Valley, we say, "Well done" and "Thank you!" You are most deserving of our Conservation Award for 2001.

George McGee Service Award — Fenja Brodo

It is hard to adequately describe and acknowledge the all around excellent manner in which Fenja Brodo managed and directed the production of almost ten volumes of *Trail & Landscape* throughout her editorship. Not content with simply waiting for manuscripts to arrive, Fenja asked many amateurs and professionals to share their observations and insights on a wide variety of natural history topics. She particularly encouraged the contributions of young people and inexperienced authors, and she enthusiastically sought out the best natural history poets to add dimension to the journal. Her keen interest in natural history and scientific background led her not only to edit manuscripts, but also to test keys in the field and meticulously check facts against reliable literature. Many authors thanked her for her attention to detail, and for her patience and diplomacy. Always sensitive to the needs of the Club, she carefully prepared the publication team for her replacement so that the transition was seamless for the reader and for the hard working production group as well. In fact, she continues to serve as an associate editor, helping our new editor, Karen McLachlan Hamilton, whenever she is asked, and carefully proofreading each issue. Fenja's dedicated service as editor of *T&L* for most of the 1990s makes her eminently qualified for the Club's service award.

Anne Hanes Natural History Award – Robert Bracken and Christina Lewis

Some animals seem to get overlooked by naturalists despite being colourful, lively, and diverse. Dragonflies and damselflies are good examples. Fortunately for OFNC members, Bob Bracken and Chris Lewis remedied this situation by making these insects the object of their keen observational skills over the past five years. Their passion for "dragons," as they call them, is demonstrated by their remarkable checklist of the species found in the Ottawa Region and published in *Trail & Landscape* in 1998. The list is packed with information on the precise habitat preferences of each species, their flight periods, and notes on their abundance in the region. It is based on a great deal of field work by Bob and Chris all over the region, supplemented by careful attention to the scientific literature. As Chris and Bob continued their "quest for dragons" (to use their own words), they frequently visited Morris Island, which turns out to be a Mecca for dragonfly and damselfly enthusiasts. To share their deep interest in these fascinating insects, Bob and Chris led a field trip for the OFNC in July of 2000 finding 30 of the 66 species they have recorded so far from the island. All their exciting finds were recorded in a fine article in T&L, illustrated by beautiful and accurate drawings by Chris. For their enthusiastic work in opening the world of Odonates ("dragons") to members of the club and publishing two fine articles on their natural history, the Club is proud to present the Anne Hanes Natural History Award to Robert Bracken and Christina Lewis.

Member of the Year – Eve Ticknor

In honouring Eve Ticknor as Member of the Year, we do indeed mark a year of tremendous and devoted service to the club. Many club members will know Eve as the OFNC's Peregrine Falcon watch coordinator for the last three years. This year-round job, all voluntary, requires stamina, patience and diplomacy. For several weeks every year, it is intense and sometimes heartbreaking. There are few, if any, other volunteer jobs within the OFNC, with the possible exception of gardening, where one deals with matters of life and death. Every year the falcon watchers begin the breeding season full of hope: that the peregrines will nest, that young birds will hatch, that fledglings will clamour, then soar, safely amidst the downtown towers.

One thing that makes Eve such a good falcon watch coordinator is that she loves the falcons. 2001 was a particularly trying year for Eve and the other volunteers who

dedicate themselves to ensuring the birds' survival. In 2001, peregrine parents Connor and Horizon produced three eggs. One hatched but the other two didn't. When eggs turn out not to be viable, it's possible to adopt. In 2001 the Canadian Peregrine Foundation purchased a hatchling to accompany the bird that did hatch. The parents fed and nurtured the young birds — chicklets, as Eve would call them — until they were ready to fly.

In years past, young falcons, and even once an adult, have flown to their death by crashing into glass-walled buildings, thinking the reflections ahead were merely open sky. Every year, falcon watchers and others have tried to find ways to break up the reflections. In 2001, with the assistance and leadership of the Ontario Ministry of Natural Resources, the most dangerous nearby building was festooned with colourful flags to make it look more like the imposing wall that it was.

In spite of this effort, the 2001 watch was cut short. On June 24th, on their first day of flying, both young birds died when they were unable to fly strongly enough to avoid colliding with a different building.

The falcon watch goes on, every year with new hope. Every year requires building and rebuilding relationships with downtown property owners, building managers, the Ontario Ministry of Natural Resources, the Canadian Peregrine Foundation, many volunteers and members of the public.

Eve further distinguished herself in 2001 by taking on the job of bird feeder liaison for the birds committee. This much needed role involves fielding comments and concerns from members and the public, and directing them to the appropriate bird feeder caretaker. It requires tact, problem-solving skills and energy. Eve's willingness to help here has been a great blessing.

Other falcons stole Eve's heart in 2001, too. She independently conducted a survey of urban-nesting Merlins in Ottawa. She has jumped in to assist with other projects, including helping with local arrangements for the annual Taverner Cup birding competition. We're sure there must be more than we know about. Eve tends to take on work quietly, just pushing up her sleeves and doing it. Eve is also active in her housing co-op, including as a choir member. Somehow she holds down a day job as a teaching assistant for special-needs children. Eve is busy every year, but we recognize 2001 as a special year of service and achievement.

IRWIN M. BRODO, CHRISTINE HANRAHAN,
BEVERLY MACBRIDE, and SHEILA THOMSON
CFNC Awards Committee

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Advice for Contributors to *The Canadian Field-Naturalist*

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